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THE MONTH.

A NEW TRAMWAY BRAKE.—The extraordinary tramway accident at Ramsgate has been instrumental in leading to the introduction of a valuable adjunct to tramcars, in the form of a third brake, which at the suggestion of Colonel Druitt has been applied to the Pennycomequick line of the Plymouth Corporation, to prevent the cars from running backwards on steep gradients. The appliance to which we refer is the joint invention of Mr. C. R. Everson and Mr. W. H. Sleep, and has been tested with very satisfactory results, in the presence of the Tramway Committee, near North Road Station, Plymouth. At the time this trial was made the rails were very slippery owing to heavy rain, but when current was cut off and the car commenced to run backwards down the hill, its motion was arrested within two feet by the use of the new brake. Similar results were obtained when the car was running at high speed. Another advantage offered by the new brake is that in starting a car which has been stopped on a rising gradient the wheels are perfectly free, and no current need be wasted in overcoming the resistance of brakes as hitherto. The new brake consists of a scutch, extending across the whole width of the car, arranged so that it can be lowered by a quarter turn of a wheel on the driver's platform. A slight backward motion of the car brings the wheels against the scutch, whose resistance is increased by the fact that it is also in contact with the whole width of the track.

THE "AMERIKA" AT DOVER.—If evidence were required of the advantages secured for this country by the forward policy of the Dover Harbour Board, it could be found in the recent visit of the Hamburg-American liner *Amerika* to the ancient Cinque Port. As our readers may be aware this magnificent vessel, built by Messrs. Harland and Wolff at a cost of nearly one million sterling, is the largest steamship in the world, having a measurement of 22,500 tons, and providing accommodation for some 4,000 passengers. Thanks to the deep-water landing stage provided by the Prince of Wales Pier, Dover is the only port in the world where a steamship of this magnitude can draw up alongside a railway station. The growing importance of Dover as an international port is shown by the fact that more than thirty Transatlantic and other ocean liners call regularly every month. It is probable that before many years have elapsed, a very large proportion of the Atlantic passenger traffic will pass through the Kentish port. At the present time the chief obstacle is the inadequate support given to the harbour authorities by the South Eastern and Chatham Railway Company, whose excessive express fares and second

rate rolling stock contrast most unfavourably with the facilities offered by the companies interested in the ports of Liverpool and Southampton.

THE OXFORD TRAMWAYS.—Interesting reading is to be found in the reports of Mr. Sellon and Mr. Worby Beaumont to the Oxford Town Council, upon the relative merits of electric tramway and motor omnibus services. The opinions of these experts are diametrically opposite. Mr. Sellon, who favours the surface-contact system of electric traction, estimates the receipts at 10*d*. per mile and the expenses at 6*d*. per mile. Mr. Beaumont, believing that the motor vehicle offers the best solution of the problem, puts receipts at 11*d*. per mile and expenses at 8·7*d*. per mile. In view of the fact that the existing horse tramways only cost 8·44*d*. per mile, and bearing in mind the somewhat unreliable character of data as to the working costs of motor omnibus services, it is not surprising that the town council decided to adopt the recommendations of Mr. Sellon, in favour of electric tramways.

MINUTE MEASUREMENTS.—In a communication to the Royal Society, Dr. P. E. Shaw gives details of a micrometer capable of indicating differences down to one fifty-millionth of an inch. The purpose for which this instrument was devised is stated to be the measurement of the sparking distance through air of electric current with the tension of one volt. The apparatus comprises a series of levers by which movement is multiplied 2,000 times, operated in conjunction with a micrometer screw enabling readings of one twenty-five thousandth of an inch to be made.

SUPERHEATED STEAM IN LOCOMOTIVES.—We have already given prominence to the views of Continental locomotive engineers upon the practical utility of superheated steam, and it may interest many of our readers to know that some railway companies in Canada and the United States are making experiments with superheated steam locomotives. One prominent Canadian company, upon whose system one or two engines of the kind have been running for some years, are now preparing for a considerable extension of the superheating system. Several of the more prominent railways in the adjoining country are experimenting with superheating locomotives, and there are indications that many more will be applied within the next year or two. In a paper read before the Franklin Institute, Mr. W. M. F. Goss, Director of the Engineering Laboratory, Purdue University, discusses in a very instructive manner the development and present state of this most recent phase of locomotive engineering, giving illustrations of the most promising forms of superheating apparatus that have been introduced. Speaking generally, American engineers appear to follow the lines of the "Schmidt" design very closely, although certain modifications have been introduced in recent superheaters.

IRON OR STEEL?—So largely have the manufacture and use of mild steel increased within recent years, that wrought iron has almost been forgotten. Experience shows, however, that steel is far more susceptible to corrosion, although metallurgists and chemists can offer no reasonable explanation of this peculiarity. Harbour engineers invariably stipulate that wrought iron shall be employed for structures exposed to sea water, having found the greater durability of that variety of metal. The Department of Agriculture at Washington are now engaged upon an investigation into the complaint of farmers throughout the West that wire fences, formerly good for thirty years, now begin to fail at the end of three years. These are only two examples of the general experience as to the comparatively rapid corrosion of steel in distinction from wrought iron. Until metallurgists succeed in producing mild steel that possesses greater resistance to corrosive influences than the material now available, engineers would do well to employ wrought iron for many purposes. But it is very difficult to be sure of obtaining the material specified absolutely free from the admixture of steel, except at prohibitive prices. A want of the present day seems to be the introduction of a process for producing genuine wrought iron at the price of steel, so that iron may be more freely employed in cases where resistance to corrosion is a more important feature than high tensile strength, hardness and resistance to abrasion.

THE CANADIAN PACIFIC RAILWAY.—If evidence were required of the energetic policy pursued by the directors of the Canadian Pacific Railway Company, it would be amply provided by the resolutions passed at the annual meeting last month. On that occasion the shareholders approved the construction of the Wolseley-Reston branch, the lease of the Nicola Kamlops and Samilkameen Coal and Railway Company, the agreement with the British

Columbia Electric Railway for the working of the Vancouver and Lulu Island Railway, the traffic agreement with the Spokane International Railway Company, the lease of the Esquimalt and Nanaims Railway, and the acquisition of the property of the St. John Bridge and Railway Extension Company. Moreover, resolutions were passed authorising the expenditure of £1,500,000 upon additional locomotives, passenger cars, and goods wagons, and the issue of debenture stock to the value of £800,000 for defraying the cost of two new Atlantic steamers. It is extremely satisfactory to learn that there is every prospect that the large revenue of the company is likely to be considerably increased during the current year, and that the line between Montreal and the Pacific Coast may justly be placed in the front rank of Transcontinental railways.

THE LONDON COUNTY COUNCIL TRAMCARS.—There is reason for congratulating the London County Council on their attitude with regard to the tenders received for the supply of new tramcars. The lowest tender for the car bodies was received from a Hungarian firm, but as the labour conditions were not in compliance with the specification, the Highway Committee, acting under the authority of the Council, accepted the next lowest offer by Messrs. Hurst, Nelson & Co. of Motherwell. Similarly, the lowest tender for the bogie trucks required for the cars was that of the same Hungarian firm, and after due consideration the committee again resolved to accept the next lowest tender, by the Brush Electrical Engineering Company of Loughborough. These two decisions come as a pleasant reversal of the Belgian rail policy which excited so much adverse criticism a year or two back, and as the London County Council seem to recognise the advantages of protection as applied to the metropolis, it may be hoped that they will in future become equally ardent supporters of the movement for fiscal reform generally.

THE IRON AND STEEL TRADES.—Judging from all accounts, the iron and steel industries of Great Britain are just about to enter upon a period of great prosperity. We have already alluded to the satisfactory condition of things prevailing in Scotland, and are glad to receive equally reassuring reports from other great industrial centres. In addition to revival of the home demand, the export trade shows undoubted signs of renewed strength. Orders are coming in freely from South Africa, Australia and South America, but activity is still more marked in trade with the Far East. Both Japan and Russia are now embarking upon a campaign of peaceful character and involving the purchase of railway material, contractors' plants, and new ships upon a scale of much magnitude. Further, the bulk of the orders for rehabilitation of the Russian navy will most probably fall to the lot of British firms. Consequently there are good grounds for believing that the present revival is only a foretaste of what is to come.

BRITISH CANALS.—At the conference of the Associated Chambers of Commerce held in Liège, a resolution was passed favouring the appointment of a Royal Commission to inquire into the condition of the British canal system and internal navigation generally. No doubt the adoption of this course would have the effect of collating a large amount of useful information, but we do not see that it could advance matters in any other way. Public works are left very largely to private enterprise in this free and somewhat happy-go-lucky land. We are so independent and self-reliant that the idea of a Public Works Ministry has never been seriously considered. Yet, the admirable results attained by similar departments in Continental countries, in Egypt, and in British possessions and colonies, lead to the conclusion that the systematic design, execution and administration of various great public works by a central authority would be for the benefit of the nation at large. British canals and navigable waterways, in particular, ought to be under a central board or Government department. If this were the case, there might be some prospect of a regenerated canal system, as useful to the industrial and mercantile classes as the admirable waterways of Holland, Belgium, and other countries. The only practicable alternative is the creation of a canal trust endowed with ample powers and financed by private capital. But the constitution of a public authority would be preferable for many reasons.

THE IMPROVEMENTS AT EUSTON STATION.—Although not quite completed, the extensive alterations at the London and North Western terminus are so far advanced that the visitor can obtain a very good idea of the important improvement that has been effected. An additional area of some twelve acres has been included within the station boundaries, involving the demolition of two

hundred houses, the obliteration of an entire street and the erection of new dwellings for the displaced population. By the provision of a new track to and from Willesden for the use of empty trains and locomotives, all four lines running into the station are available for passenger traffic instead of two as heretofore. Trains arriving can be transferred through subways to the down lines, so that incoming and outgoing traffic shall not be hindered by shunting operations. Two spacious carriage sheds have been built to provide accommodation for storage, cleaning and other purposes, the larger shed covering an area of three acres and containing 1½ miles of lines. Both sheds are in communication with an extensive network of points and crossings, which facilitate the marshalling and make-up of trains to such a degree that the transference of empty trains to Willesden will be materially reduced. Other noteworthy reforms are the installation of points and crossings to suit modern rolling stock, and the adoption of electrically-operated signal apparatus.

BELGIAN CEMENT.—A report by the British Consul-general at Antwerp draws attention to the practice of Belgian cement manufacturers in labelling their packages with trade marks and other descriptive matter in the English language, with the evident intention of leading consumers to believe that they are receiving British-made products. The consul-general appears to be under the belief that the barrels or bags of cement are invariably marked "Made in Belgium." Unfortunately this corrective is not invariably applied owing to the conscientious perversity of the British Customs authorities, who decline to apply the provisions of the Merchandise Marks Act unless the packages bear the full name or the full initials of the British importer. Foreigners are fully aware of the way in which the Act has been shorn of its protective character, and are only too ready to avail themselves of the loophole thereby offered. Why the commissioners should have gone out of their way to nullify the obvious intention of the Act, we cannot imagine, and it is quite time that the matter should be set right. At present, consumers are very liable to imposition, believing that all foreign products must be marked with the name of the country where they are made. The only real safeguard is to demand that all packages shall bear the full name and address of a well-known British firm. It is really most annoying that the fraudulent devices of foreigners should receive the tacit support of the authorities who are paid to protect our own industries.

COAST PROTECTION WORKS.—Recent gales have served once more to demonstrate the futility of costly and massive masonry works built upon strata that is easily undermined and destroyed by the action of the sea. At Scarborough a considerable section of the new marine drive has been washed away, at Southwold the newly completed protective works are virtually demolished, and heavy falls of cliff have occurred at more than one place on the East Coast. On the other hand stretches of the coast line that are protected by ample accumulations of beach material and grass-grown sand dunes have resisted the action of high tides and heavy seas in a most satisfactory manner. This serves to point the moral that the best way of safeguarding our shores is to promote the collection of sand and shingle by means of groyning, above and below low water mark. In this connection we may refer to two excellent types of groyne construction. One is the "Owens-Case" reinforced concrete groyne which offers advantages impossible of attainment by any timber groyne, and the other is the "Allanson-Winn" cable groyne for the prevention of erosion in deep water beyond low-water mark. The separate or joint application of these systems would be of undoubted value at many threatened points on the East Coast, and further protection could be provided at a very moderate cost by the conservation of sand dunes by marrum grass in the manner so successfully adopted by Mr. Rider Haggard at Kessingland, near Lowestoft, where the height of the beach is said to have been raised several feet by the help of this grass.

Swing Bridges.

Their Construction and Design.

By W. HANNAH McLEAN, A.M.Inst.C.E.

I. Construction—Description of Types.—The progress of civilisation and the consequent congestion of our lines of communication demands the frequent adoption of the movable bridge. The idea is by no means modern, as the drawbridge over the castle moat was an effective contrivance of this nature which served its day.

Rankine enumerates the various kinds of moveable bridges thus :—

1. By turning on a horizontal axis. 2. By turning about a vertical axis. 3. By rolling horizontally. 4. By lifting vertically. 5. By flotation.

The swing bridge is of the second class, and it is probably the most important and most largely adopted of any type of movable bridge. The arrangements of a swing bridge generally consist of the superstructure or bridge proper, and this is attached to a centre pivot round which it is turned by the motive power, the swinging deflection of the girders being taken out when the bridge is closed.

Probably one of the earliest forms of swing bridge in this country is used to carry the roads over the Caledonian Canal. Fig. 1 shows one of these bridges. They are worked by manual power and consist of two leaves, and although this necessitates a duplication of the parts, the type is eminently suited to the use of cast-iron. Fig. 2 shows the bridge open.

It will be found convenient to classify the various types of swing bridges under two divisions, viz :—

I.—Bridges having unequal arms or spans and requiring a support at the tail end, the excess weight of the long arm being counterbalanced by kentledge (usually cast-iron blocks) placed on the short arm.

II.—Bridges having equal arms or

FIG. 1.

FIG 2.

EARLY TYPE OF SWING BRIDGE OVER THE CALEDONIAN CANAL.

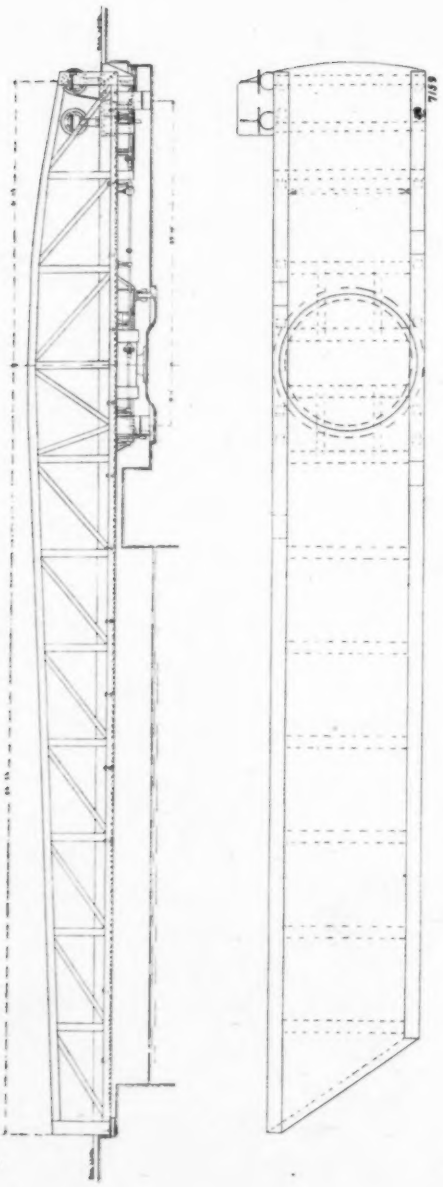


FIG. 3.

spans, the ends of which hang free when swinging. These, when open, are simply balanced cantilevers revolving round a fixed centre.

Considering type I., we find that most of the bridges of this class are associated with a slight bascule movement. This is obtained by either raising the centre pivot or by lowering the tail end. When the long arm is the heavier, the tail rollers rise against an inverted roller path, and on the lift of the centre press continuing the nose is raised off its bearing. If the tail arm is the heavier, the tail end sinks and the rollers fall on the tram plate, the nose rising at the same time.

The ratio given to the arms is a matter of some importance. The chief objection is the increase in turning power required owing to the weight of the kentledge. This, of course, is counterbalanced by the saving in cost of kentledge over steelwork, so that the most economical ratio differentiates between these two limiting conditions. It is found to be about 0·66, but this proportion is often impracticable, and there is great diversity among existing types being generally much lower.

The following detailed descriptions are of recently-erected bridges of this type, which possess a number of features worthy of note. Figs. 3, 4, 5 and 7 show details of the bridge carrying the Invergarry and Fort Augustus Railway over the Caledonian Canal. This bridge has a short arm of 31 ft. 11½ in., and a long arm with a skew end giving 86 ft. 5¼ in. and 78 ft. 9 in. length of girders. This gives a proportion of the

arms of about 0·4, the total weight of the steel-work in the superstructure is about 97 tons, while the kentledge is about 62 tons. The main girders are at 15 ft. 2 in. centres, and are of the bow-string type, having a depth 9 ft. 6 in. at the pivot. The bracing is of the "N" type with verticals 10 ft. 8 in. apart, and all the web members are of built "H" section, while the booms are of the usual trough section. Fig. 3 gives a general plan and elevation of the bridge. The whole floor is covered with sheet-iron plates at rail level. The swinging the weight is carried on a centre pivot, and there is a ring of steadying wheels running on a cast-iron race. The whole arrangement is shown in Fig. 3. The pivot has a ball and socket bearing which allows of a certain bascule movement in the bridge, and the superstructure is supported by cross girders attached to the pivot casting by bolts. Fig. 5 shows a plan and section of the pivot, and also the method of attaching the cross girders. The bridge is swung by spur-wheel gearing operating on a cast-iron rack round the back of

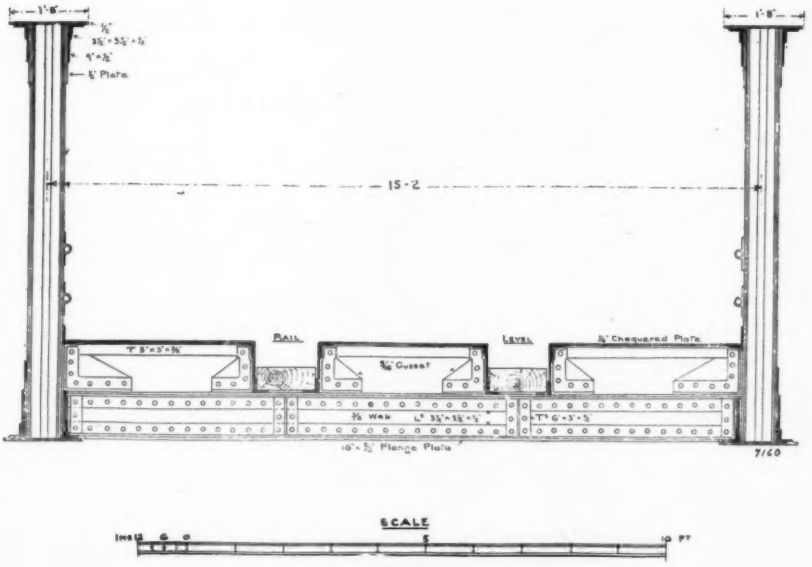


FIG. 4.

cross section in Fig. 4 shows the details of the flooring. The superstructure is supported at three points when the bridge is closed ready for railway traffic, viz., the bearing at the end of the long arm, a bearing at 6 ft. 11 in. from centre of pivot on the long arm, and one at 29 ft. 10 in. from centre of pivot on the short arm. The two latter are adjustable bearings consisting of toggles resting on stools exactly under the main girders. When the bridge is open and the pit. Manual power is used, the time occupied in the whole operation of raising the ends and turning the bridge being four minutes. The operating platform is placed at the tail end (Fig. 3), and there are two headstocks and handwheels, one being used for working the toggling gear and the other for turning the bridge. To open the bridge the nose must first be lifted from its bearing, and this is effected by withdrawing the toggles which allows the bridge to rest

on the pivot. At the same time this gives a cant upwards at the nose owing to the surplus weight of kentledge at the tail end, the steadying wheels preserving the equilibrium of the whole. The bridge is then free to turn. The process is reversed in closing. The structure rests on a concrete foundation, and at the nose there is a cylinder 7 ft. 6 in. diameter under each main girder.

The signalling arrangements across the bridge are of special interest; Fig. 7 shows the disengagers which are placed at each end of the bridge.

When the bridge begins to move, the two arms are thrown out of gear and the signals cannot be pulled over. To ensure that the bridge is properly locked in position two bolts are provided, one of which is worked from the operating platform, and the other is controlled by the signalman. This latter bolt is slotted so that it is impossible to send it home before the end of the bridge has been lowered on its bearing and the rails are at their proper level. The system is interlocked so that the signal cannot be given before the bolt is in position.

Another example of this type is the bridge carrying a siding from the Lanarkshire and Dumbartonshire Railway over the Forth and Clyde Canal shown in Figs. 8 and 9. A feature of special interest in this bridge is that the tail arm is exceedingly short as compared with the long arm. The lengths are 36 ft. 4 in. for the short arm and 116 ft. 9 in. and 97 ft. 6 in. for the long arm which is skewed at the end. This gives a ratio of about 0·33, but this proportion was necessitated by the situation of the line. The girders are of the usual bowstring type, having a depth of 17 ft. 6 in. over the pivot, and they are provided with overhead bracing. The bracing of the main girders is of the "N" type, and the booms are of trough and ties and struts are of "H" section. The weight of the steelwork is about 173 tons, and there are about 200 tons of kentledge which is built up in the last panel of the girders and also under the flooring of the bridge. The width between the main girders is 19 ft. 4 in., but this excessive width is occasioned by the line crossing on a very sharp curve. The verticals are 9 ft. 8 in. apart placed symmetrically from the centre post, and the cross girders carrying the flooring are attached at the apices. The permanent way is carried on timber way beams bolted to rolled "H" beams running longitudinally on

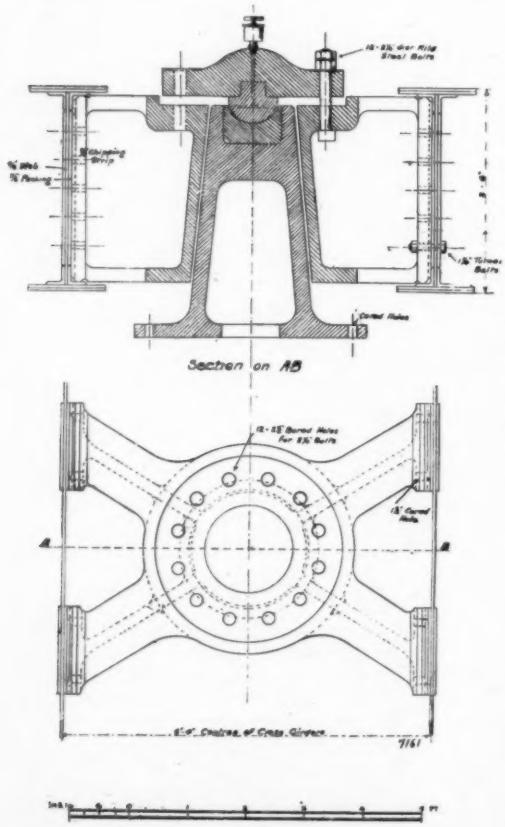


FIG. 5.

the cross girders. The flooring consists of $\frac{5}{16}$ in. plates. The bridge is opened by manual power and the operation is performed by turning the handwheel at the tail end of the bridge which is geared by shafting to a circular rack. When in position the bridge is locked at the nose by a bolt furnished with a hand-lever. The toggles under each main girder are then screwed down on the bedplates, which are planed with a slightly V face to ensure an exact bearing. The lever and handwheel for the gearing at the nose of the bridge are quite separate from that at the other end. It will be seen from Fig. 8 that the superstructure is carried on an annular girder (19 ft. 4 in. diameter), of box section, which takes the weight at four points, two from the main girders and two from the cross girders. The centre cross girder passes over the pivot and has a short curved girder at each end which act as stools. The bridge turns on a ring of conical rollers, but a portion of the weight is carried by the centre pivot. The normal position of the bridge is when open for canal traffic, and it then lies along the protective timber staging and the whole weight is carried on the pivot and rollers. A pair of toggles are provided at the tail end of the bridge as well as at the nose, so that when closed for railway traffic a great part of the weight of the bridge is resting on the toggles at each end of the main girders. The gearing and toggles are seen in Fig. 9.

The following general descriptions of existing structures will serve to illustrate type II. Bridges of this class are generally of large span, so that the mass to be moved is often very considerable.

The bridge over the river Tyne at Newcastle, which was for a long time the largest highway bridge in the kingdom, has two clear spans each of 110 ft. The weight of the swinging portion is over 1,200 tons, a portion of which is carried by a hydraulic relieving centre press and the remainder is carried on a ring of rollers. The bridge is worked by hydraulic power, and the ends are set up by four small rams, parallel blocks being inserted under the girders when at the correct level.

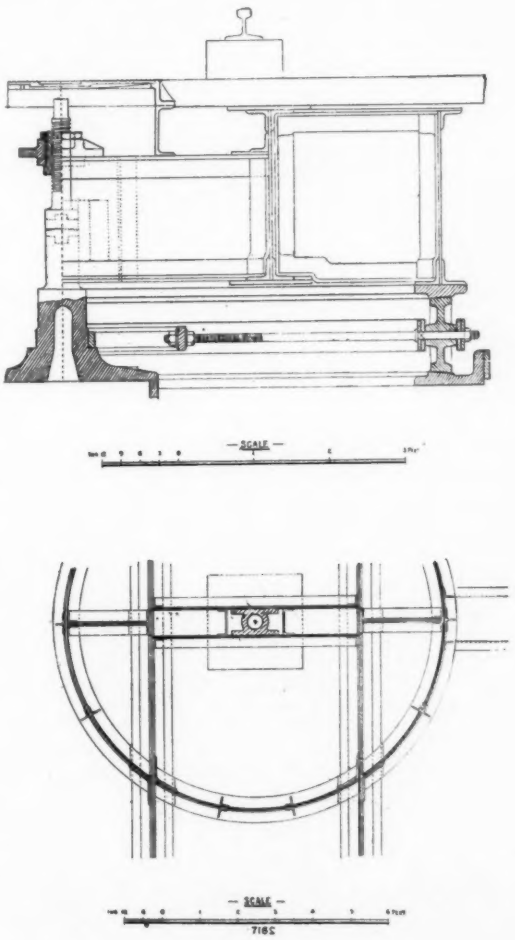


FIG. 6.

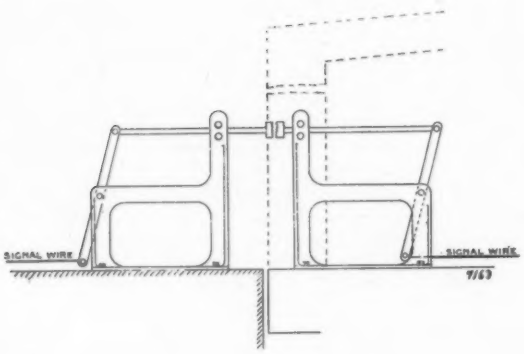


FIG. 7.

The Clarence Bridge at Cardiff is an example which presents many interesting details. The tail supports are arranged so that the whole dead load is carried by the central pier either when swinging or closed, thus the only load the tail supports have to carry is the live load when on the bridge. The ends are supported by eccentrics and rocking levers. The eccentrics for raising and lowering the rocker and lever are worked from a line of shafting underneath the flooring. The bridge is turned and locked by manual power, four men opening it in five minutes. One important feature in connection with the design is the omission of the bracing from the centre bay, which considerably simplifies the calculation of the stresses in the main girder. This bridge provides two openings each 75 ft. wide, the roadway being 41 ft. 6 in. wide, and the weight of the moving parts about 350 tons.

There are several bridges of this class over the Manchester Ship Canal, the most striking being the Barton Aqueduct. This bridge carries the Bridgewater Canal over the Ship Canal and possesses many interesting features. It is always swung full of water. The length of the swing span is 234 ft. 6 in. and the weight, including the water, is 1,600 tons, half of which is supported on rollers and the other half on a centre hydraulic relieving press which also acts

FIG. 8.—SWING BRIDGE OVER THE FORTH AND CLYDE CANAL.

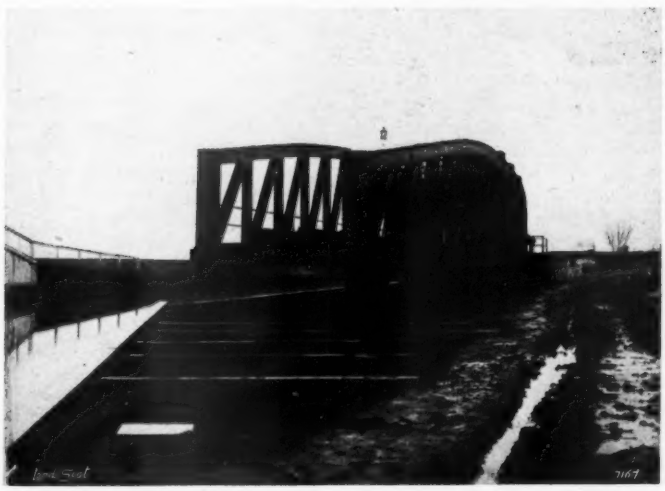


FIG. 9.—SWING BRIDGE OVER THE FORTH AND CLYDE CANAL.

as a pivot. The weight is transferred to the upper annular girder by three cross girders, the centre one passing over the hydraulic press. The turning is effected by hydraulic engines and gearing.

II. Design: Long Span Roadway Bridge.—The design of a swing bridge involves a variety of somewhat complex problems owing to the nature of the structure. In the case of a small bridge many approximations may be made, but in a bridge of large span the difficulties of design become fully developed, and a more detailed investigation is necessary.

Figs. 10 and 11 show a competitive design, made by the writer, for a swing bridge over the river Clyde (400 feet span), a description of which will serve to illustrate these problems. The swing span is carried on a pier 60 ft. wide, and has a length of 280 ft., which is somewhat longer than the Newcastle-on-Tyne bridge; the moving parts are also much heavier, the roadway being 60 ft. wide. This design introduces the novelty of supporting the ends of the swing span on cantilevers instead of on rigid supports. The cantilevers are anchored at the shore tail ends and project 60 ft. from the quays.

In this example an attempt was made to follow the principle that a bridge should be aesthetically designed; not designed first and an effort made to beautify the structure as an afterthought by the application of superfluous ornament.

No hard and fast rules can be laid down for the design of swinging girders, and each case usually requires a certain amount of special treatment. Generally speaking, however, when open, the girders may be taken as balanced cantilevers, and when closed as continuous girders, and it is in this condition that a certain complexity of stress occurs. In this design the girder when closed is taken as continuous over three supports and built without initial camber. A somewhat greater degree of accuracy is obtained if the girder is considered as continuous over the stools, and taken as of three spans. This decreases the stresses, but the effect is comparatively small. By assuming a constant moment of inertia and using the theorem of three moments the end reactions are easily

found. This assumption is on the right side, as it tends to make the girder slightly stronger than necessary. If the girder were built with an initial camber the reaction at the ends would be lessened, and might even be reduced to zero, so that the whole weight would be carried at the centre. This tends to produce hammering at the ends, and is therefore objectionable. An examination of the stresses in the members will show that when in the condition of a cantilever the top flange is wholly in tension and the bottom in compression, and these gradually alter as the continuous

tive moment occurs in either span when that span is loaded and the other unloaded; also that maximum negative moment occurs when the bridge is open and hanging free.

Maximum shear occurs in a span when that span is loaded only. The diagrams give the range of stress for any member, and also show the variation of the point of contra-flexure. The maximum live load is taken as 200 lbs. per square foot, distributed on the roadway and 112 lbs. on the footpaths. For the flooring a concentrated rolling load of 75 tons on one

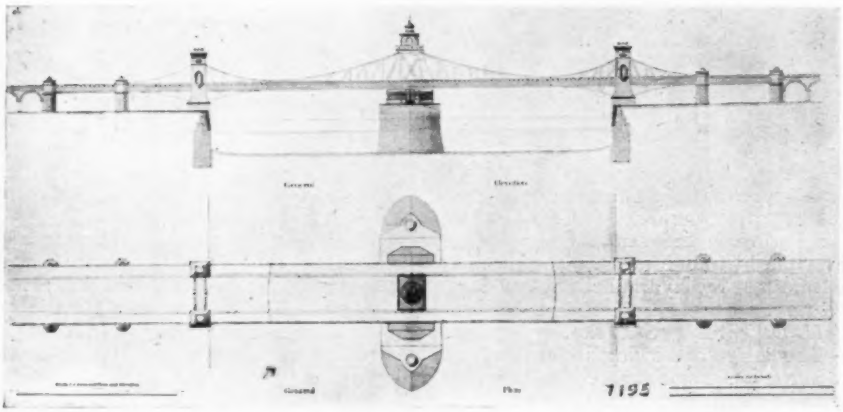


FIG. 10.—DESIGN FOR SWING BRIDGE OVER THE RIVER CLYDE.

condition is reached by setting up the ends of the girder. As the ends are raised the reactions increase, and a region of compression in the top flange and tension in the bottom flange begins to extend from the ends of the girder, the web members being affected in the same degree, and the action should end when the girder has been levelled up. Thus the girder must be designed for these two limiting conditions, the first when the end reaction is zero and when it has its maximum value.

Fig. 12 shows the bending moment and shear diagrams under the various limiting conditions superposed for comparison. It is seen that maximum positive

trolley is taken. In designing the flooring it is necessary to investigate the effect of this load on each member. The swing span is assumed to be raised through two-thirds of its deflection.

Fig. 11 shows the details of the swing span. The main girders are of the "N" type, the booms of trough section with carved webs, the upper boom being parabolic. The verticals are of box section, and the diagonals of "H" section, both with braced webs. The cross bracing of the centre panel in this example will not produce hammering at the ends as in the case of a light bridge. The cross girders, 17 ft. apart, are of box section, and the cantilevers

for the footpaths are connected by gusset plates between the webs of the boom. The flooring consists of hardwood blocks on concrete and buckle plates supported on cross and longitudinal girders and bearers. Horizontal cross bracing between the main girders is provided under the roadway, and also overhead bracing on which is placed a signal cabin and lighthouse. The roadway is 34 ft. wide, and the footpaths are each 9 ft. 6 in. wide. The total weight of the swing span is about 1900 tons.

not be attained, as the deflecting of the main girders tends to take the weight off the centre cross girder, which would then leave the weight on four points.

This objection is successfully overcome in the case of a load supported on a ring at six points in Fig. 6, which shows the method of supporting the superstructure in a bridge recently erected for the Carron Company at Cadder. From the figure it will be seen that there is an adjustable centre pivot, and this, while ensuring that the

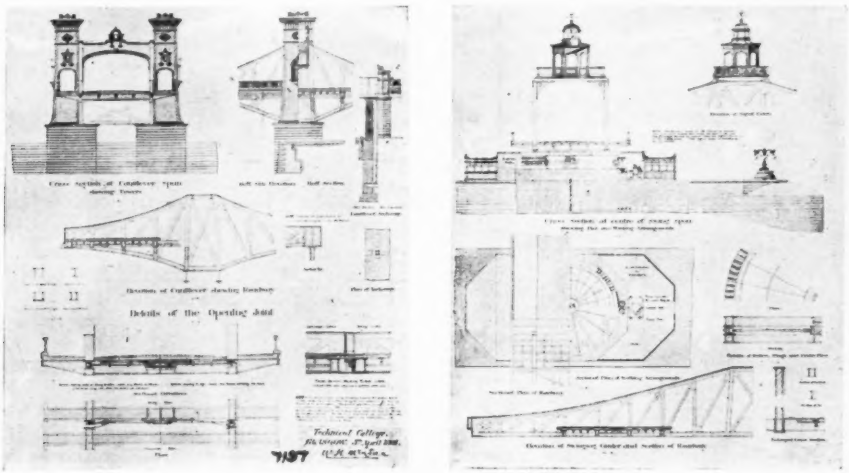


FIG. 11.—DESIGN FOR SWING BRIDGE OVER THE RIVER CLYDE.

As shown in the figure, this weight is distributed by radiating girders on the annular ring and hydraulic relieving press in a manner which ensures an equal distribution of the weight on the ring at eight points, and also that the press shall take its due proportion, which is in this case one-fifth.

There are a number of systems of distributing the weight of the superstructure, but this one would seem to be a very satisfactory solution. The system adopted on the Barton Aqueduct, already referred to, is evidently supposed to distribute the weight at six points on the ring, but it is probable that this may

weight is equally distributed on the rollers, also ensures that the pivot takes its due proportion of the load in a most efficient manner. There is no doubt that, unless the weight is distributed on at least six points, excessive wearing of the rollers at the points of application ensues.

Referring to Fig. 11, it will be seen that the circular girder is supported on a ring of 96 cast-steel rollers, 15 in. diameter, held in position by steel framing, and these in turn are supported by a lower circular girder which distributes the weight on the pier. The rollers run on cast-iron paths bolted to

the upper and lower girder. In designing the annular girder, it should be taken as a simply supported beam uniformly loaded between the points of application, and the continuity of the girder can be placed against the additional stress due to curvature. The size of the hydraulic press, which of course is supposed to have no vertical movement, would be governed by the pressure available, but is shown 4 ft. diameter. The rollers are calculated to take 2,000 lbs. per lineal inch, and they are strong enough to take the whole of the load. The usual diameter of roller adopted is between 12 in. and 24 in., but the disadvantage of a large diameter is increased coning, and therefore increased collar friction.

The resistances to be allowed for in calculating the turning power are as follows:—1. Wind pressure (neglected with equal arms). 2. Roller and collar friction. 3. Friction of centre pivot. 4. Inertia. 5. Machinery friction. The resistance in this case due to roller and collar friction, assuming a co-efficient of rolling friction of 18 lbs. per ton, is 1·4 tons when reduced to the radius of the rack. The resistance due to friction of the hydraulic centre pivot, assuming a co-efficient of ·2 between the ram and the packing, is 2·15 tons when reduced to the radius of the rack. The resistance due to the inertia of the bridge is in this case a very large quantity, being 8·15 tons when reduced to the radius of the rack, and although the work done in accelerating the bridge is given out during the retardation, yet the engine must be able to overcome it. The friction of the machinery is allowed for by summing all the other resistances and doubling, which in this case equals 23·4 tons. Now, taking the available pressure at 1,000 lbs. per square inch, and that the bridge is to be opened in one-and-a-half minutes, the horse-power of the engine would be 35. The bridge is worked by hydraulic power from an outside supply. The engines, in duplicate, are of the three-cylinder type, and geared by spur-wheel gearing to the cast-iron rack bolted to the upper circular girder, and they are arranged to open and close the bridge in three minutes. The bridge would be worked by telegraphic signals from the cabin to the engine-room, and all the motions, interlocked to ensure perfect sequence, are controlled from the engine-room. The reason for the frequent adoption of hydraulic power is that swing bridges are generally in a position where this form of energy is available, such as at docks, &c. The hydraulic supply pipes must, of course, be well protected, and it is recommended to mix the water with glycerine as a protection from frost. Electrical power will no doubt come largely into use in the future.

Fig. 11 also shows the details of the cantilever span. In this case the cross girders are attached to the vertical members of the main girders, which are well braced both vertically under the cross girders, and horizontally under the flooring. The main girders are secured to the piers by bolts and plates, and are also anchored at the shore tail ends. This anchorage, which is designed to balance the reaction from the swing span, consists of a tie of box section carried down a circular shaft and securely fixed at the bottom to cross girders and distributing plates. The shaft, which is 5 ft. diameter, would require to go down through the pier for a depth of about 30 ft. below the foundations and be lined with concrete, as shown, to give the necessary superincumbent weight. The towers, designed in the renaissance style of architecture, are of sandstone ashlar and carried upon granite-faced piers. When the bridge is open for river traffic, all road traffic would be stopped at the arches. The bracing and anchoring of the cantilevers gives a very high rigidity approximating to a solid pier and capable of resisting severe shocks. The details of the members are similar to those on the swing span, and all the booms are parabolic, the lower ones having angle irons on the insides of the webs so that they are increased in value as struts.

It can be shown that if one end of a balanced cantilever is supported

the other end deflects an amount equal to double that it would otherwise do. By setting the shore end of the cantilevers with an initial depression equal to the deflection due to their own dead load and the live load which can come on them, while reducing the deflection at the outward end also ensures that the anchorage is brought into play, and destroys to a great extent the couple which would exist at the foundation bolts of the truss. If no depression were given the foundation would do nearly all the work, and the stress on the anchor ties would probably be reversed. By giving this depression there is practically no load on the anchor piers, and the box ties must be designed to take the tension due to the live load at the outward end of the cantilever, plus the reaction from the swing span.

Fig. 12 shows the bending moment and shear diagrams for the cantilever under various forms of loading, and from these the maximum and ranges of stress are obtained. It will be seen that the maximum condition obtains when the outward span is loaded and taking the reaction from the swing span, also that when there is no load on the outward span and the shore span is loaded there is a slight reversal of stress at the end of the latter, and the anchor tie will then be in compression. This would be quite a probable loading to occur. It is shown that the effect of the initial stress is to set up a couple which must be resisted by the foundation bolts. It is probable that when the outward span is fully loaded and taking the reaction from the swing span this couple will be reversed, but to what extent is uncertain, as it depends on the elasticity of the various members. It may be assumed, however, that the anchors take all the reaction, as shown in the

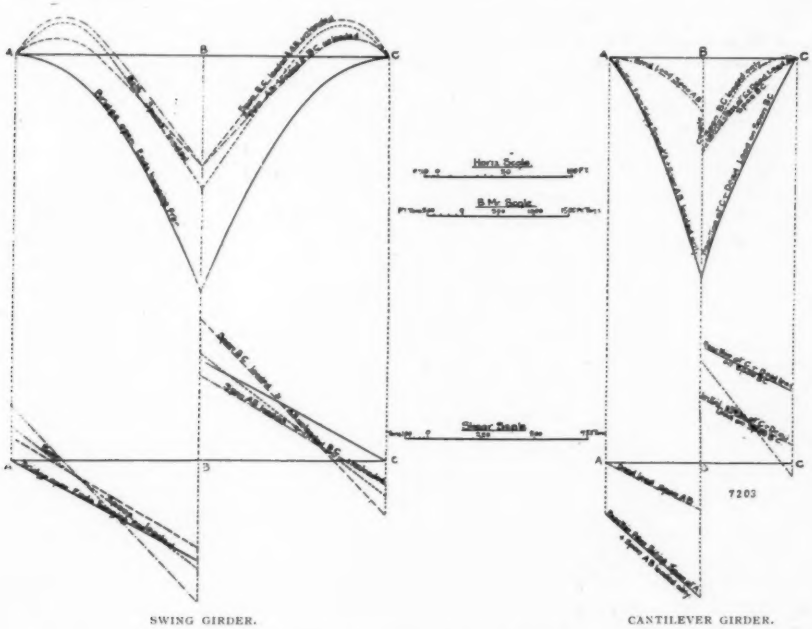


FIG. 12.—BENDING MOMENT AND SHEAR DIAGRAMS.

diagram, and this has the merit of being on the safe side at least.

The joint between the ends of the swing girders and the cantilevers involves one of the most interesting problems in the design. The details are shown in Fig. 11. It is formed by overlapping the swing girders on the cantilevers for a length of 2 ft., with a space between the laps for the working gear. The swing span carries this gear, which consists of an arrangement of bearing blocks and toggles, worked by direct action from two separate sets of double-acting hydraulic cylinders operating both sides simultaneously. The hydraulic power is obtained by leading pipes from the pier along the bottom flanges of the main girders. The bearing blocks, when in position, transfer the load from the swing girders to the cantilevers, the toggles being used for thrusting the girders apart to allow the bearing blocks to be moved. These bearing blocks are steel castings carried by cast iron guides on a circular path, taking the blocks clear of the top tables of the cantilevers, which they would otherwise foul in opening the bridge. The deflection of the cantilevers is reduced to a minimum by giving them as great a depth as possible. The deflection of the swing girders, when hanging free, is about 3 in., while the maximum deflection of the cantilevers is about 1 in. When the bridge is closed the swing girder is raised through two-thirds of its deflection, and the joint would be perfectly tight and free from hammering under all conditions of loading. When the bridge is open and the girders hanging free, there is ample clearance allowing for the rise of the cantilever when relieved. The bridge is opened by thrusting forward the toggles, which slightly raise the ends of the swing girders, allowing the bearing blocks to be withdrawn. The toggles are then released and the girders hang free. The process is similar in closing, the bridge being brought to rest in position without shock, by the spring bolts between the ends of the girders. The motions, which are interlocked, are controlled from the engine room.

The deflection of 3 in. in the swing span is the maximum which can occur, the ends hanging free, and of course without load. This includes the additional deflection due to range of temperature, the calculation being based on an assumed difference of temperature of top and bottom boom in summer. To obtain this figure it is necessary to first calculate the additional stress due to temperature, and this, added to the initial stress, is used in the calculation for the total deflection. The deflection of the cantilever which is in great part due to the reaction from the swing span, is similarly obtained.

Regarding the effect of change of temperature, we know that with each degree of change there is a proportional change in the strain. In the ordinary girder, supported at the ends, this change tends to straighten it, while in a cantilever or swing girder with ends free it has the effect of increasing the deflection. This is due to the fact that the heat of the sun beats directly on the top boom, while the lower boom is usually quite in the shade. Thus the expansion is almost wholly in the top member, so that the deflection is seriously affected, and when there is a great variation in the temperature this becomes most marked. It is evident, therefore, that unless a sufficient clearance is allowed it may be necessary to provide adjustable bearing plates. The point for consideration might be whether the expense of these would be greater than the increased cost of working to give the greater clearance. To remedy this evil somewhat in swing bridges, the upper flange might be covered on top with a layer of bituminous material, which would certainly tend to equalise the temperature of both flanges and so reduce the deflection.

These are the more important points peculiar to the design of swing bridges and demanding special consideration; the details are dealt with in the same manner as for ordinary fixed bridge work.

A Comparison of English and American Drawing Office Methods.

By A. H. GIBSON, B.Sc.

A SHORT time ago the author had the good fortune to be able to spend some months as an assistant draughtsman in one of the largest mechanical engineering works in the middle west of the United States of America, and as this experience followed on that of many years spent in the works and drawing offices of one of our foremost mechanical engineering firms, a comparison of the methods of manufacture and of office routine and procedure as practised in these two works, from the standpoint—not of the manufacturer, or of the trades-union delegate—but of the humble but necessary draughtsman, may be of interest.

The American firm has a world-wide reputation, and at the works in question, which were about twenty-five years old, employed some 1,600 men, including a drawing-office staff of about 80, divided into four departments respectively devoted to the preparation of drawings and specifications for Blowing Engines, Mill and Electric Station Engines, Milling Machinery, and Mining Machinery.

The buildings, which were conveniently arranged, were, however, shortly to be given up for new and more commodious premises, which were almost completed on the occasion of the author's visit.

The drawing office is well equipped, each draughtsman working at an adjustable draughting table, with sliding parallel rulers. The Tee square, as usually known in an English drawing office, is quite unknown. Many of the tables are fitted with a new combination of parallel levers, jointed to give a parallel motion to a graduated rule, which thus takes the place of Tee square and scale combined. As the rule can be arranged at any angle, it will be seen that for many purposes, such as setting out stress diagrams for roof or bridge work, this machine is extremely convenient. For ordinary draughting work, however, especially in the making of a large drawing, the ordinary sliding Tee-square, with grooved guides and wire and pulley adjustments, is generally preferred, the weight and inertia of the moving parts of the combination making it rather difficult to easily and quickly adjust the ruler to any given line.

All drawings are made on brown paper, instead of an expensive white paper, as in the English drawing office, and are then traced by tracers. On each drawing is placed a specification, including every part shown on that particular drawing, and giving the pattern number – if a casting—together with the material; and the number of each casting, and any other details which may assist the order office staff in making out the order form for the works.

No line shading or colouring is allowed on any drawing or tracing, the book of office rules given to the new draughtsman, informing him, in typical American style that "our drawings need no frills."

All tracings are numbered in the right hand bottom corner, with the drawer number, and with the number of the tracing in that drawer, the same numbers being entered up, along with a general description of the engine detail traced, in a card-file. It is thus possible to at once get the number of any particular drawing, and to go directly to the drawer in which it is kept. All tracings are kept flat in drawers. Blue prints are taken from

each tracing as required for the various shop departments—no tracing being allowed to leave the office.

The office hours are longer than is usual in an English drawing office, being from 8.0 a.m. to 12.0 noon, and from 1 p.m. to 6.0 p.m., as against the average English hours 9.0 to 12.30, and 1.30 to 5.30 p.m. All draughtsmen are paid by the hour, the rates varying from 24 cents to 70 cents per hour, the average rate for a good draughtsman being about 40 cents per hour. During the summer months, May to September, the firm in question do not work on Saturday afternoon, the works closing at noon, but during the remainder of the year the works and office do not close until 5.0 p.m. on Saturday.

This gives a forty-nine hour week for the office in summer, and a fifty-three hour week in winter.

The office hours at the English works in question are 9.0 to 12.30, and 1.30 to 5.30 p.m., with 9.0 to 12.0 on Saturday, giving a week of forty and a-half hours.

The average draughtsman, however, would make £4 per week in the American works as against £2 5s. per week in the English works.

There is a total absence of that hustling in the American office, which is inseparably connected with one's ideas of American business. The drawings are generally finished with much more detail than in an English works, and not so much is left for the imagination of the man in the shop. In an oil-piping arrangement, for example, for lubricating the cylinders or moving parts of a steam engine, which, over here, would probably be left wholly, or in large part, to the fitter in charge of the job, every detail—junction and elbow—is shown and noted on the specification accompanying the drawing, even such details as the exact length of brass piping needed, being given.

The staff of an American drawing office generally contains a much larger proportion of men who have never been through the works than an English drawing office, and also a much greater percentage of university graduates.

In the office in question not above 25 per cent. of the staff were works men, while almost the same percentage were from Harvard, Cornell, Wisconsin, or one or other of the universities which make a specialty of engineering. The fact that a man has had an university training, is, with the American employer, about the best recommendation a man can have; with the average English employer the word "degree" is "anathema."

It was rather surprising to find that the book of reference which was used by a very large proportion of the men for engineering calculations was a work on applied mechanics by one of our English professors.*

Each draughtsman is expected to work out his own calculations, and these, together with the whole of the drawings, are checked over by a checker before any blue print is taken. The checker checks the pattern number, &c., of all the requisite patterns, notes that all standard patterns have been worked in wherever possible, and that all drawings are made to one of the three standard sizes allowed. He then signs the tracings, taking all responsibility from the draughtsman's shoulders. By this method, very few mistakes get into the workshop, though a checker with an unpleasant disposition, and who is determined to exert his authority in making a great number of unnecessary petty alterations, can create a great deal of ill-feeling in an office, as the author knows only too well.

In the works there were many points in which the management of the American works seemed superior to that of the English works.

In the first place, the ten hour day, with its two five hour shifts, and only one break for dinner, seems to have many advantages, in the way of lessening the time lost in stopping and starting work again at meal times, over the 9½-hour day, with its breakfast and dinner times, worked in the English shops. American workmen expressed

* Professor Goodman of the University of Leeds.

themselves emphatically in favour of having breakfast before they turned out in the morning; and speaking from personal experience, it certainly does away with that lacadaisical feeling with which one used to begin work at six o'clock in the old days on a cold winter's morning without breakfast.

Then the lavatory accommodation is much more adequate to the needs of the men in the American works. One notices the effect of this especially in seeing the men going home from work in the evening, for although they have done a longer day than the English workman, generally speaking, they appear a cleaner and better dressed set of men than one would see leaving an English works. There seems to be more "snap" about the way in which the men go about their work too, and a general feeling of alertness and eagerness to get a job through, which is not altogether due to the ministrations of an officious foreman. The feeling is in the air—whether it is due to atmospheric causes, as some people say, the author does not care to say. Probably, the average Englishman, when he gets out to the States, hustles more than anyone. It is surprising to note the number of foremen and heads of departments who are Englishmen; and it is not too much to say, that other things being equal—and they are not generally equal, for the Englishman has a pull in many ways—the American employer of engineering labour, would much rather have an Englishman than an American in a responsible post.

One thing which was noticable was the extensive use made of milling machines, there being as many milling machines in use as lathes. In the English works in question not one milling machine is in use, the lathe and planer being employed in scores of instances where the milling machine would remove superfluous metal much more cheaply and quickly.

It is hardly necessary to say that the finish of the American machines, would have been considered disgraceful in the English works. The American idea is summed up in an opinion expressed to the author "Gee whiz, but I guess we make our machines to work—not to put under a glass case."

It must be granted, however, that the finish of the rubbing parts of the American was equal to that of the English machine, while the accusation of flimsiness, which used to be so applicable to much American work, could certainly not be applied to the firm in question.

In conclusion, from the point of view of a draughtsman, the large American works is quite as pleasant to work in as the average English shop—more so than most—while the rate of pay is higher, and the opportunities for an Englishman are greater; but the draughtsman must have had some amount of technical training, and must be capable of doing any ordinary engineering calculations, in order to be able to take full advantage of these opportunities. The rate of pay is comparatively, as well as absolutely, higher.

From the point of view of the fitter, turner, or pattern maker, there is not that hustle in the large American works which one is led to expect, and the style of living of a fitter is much better than in England. The author knew several working men who were able to run a horse and buggy for example. No one who is not afraid to work, and who has the trade in his hands, need be afraid of not bettering himself financially by emigrating to the Western states. How far the foregoing remarks apply to the Eastern States—New York, Pennsylvania, &c.—the author cannot say from personal experience.

He believes, however, that generally speaking, conditions of labour are not so favourable there as further west, say in Wisconsin, or even further west in Colorado.

The Rapid Electro-Deposition of Copper.*

By SHERARD COWPER-COLES.

IT has been the aim of electro-metallurgists, ever since copper-refining was introduced by Messrs. Elkington in the year 1869, to increase the rate at which the copper can be deposited in a smooth form without any large increase in the voltage. The current density employed in electrolytic refineries has been gradually increased from about 8 or 10 amperes, as employed by Messrs. Elkington's and Elliott's, at Birmingham, to 20 amperes per sq. ft. as at present employed at the Anaconda works; the current density will, no doubt, be further increased in electrolytic refining plants in the near future.

It has been argued by several writers that 16 or 17 amperes per sq. ft. is the economical limit, and that beyond this limit an increase of current density means an increased expenditure in fuel, but these writers make no adequate allowance for the saving effected by the more rapid treatment of the copper, and consequently, the greatly reduced amount of copper under treatment and the interest on capital expenditure that is saved. The table given is the comparative data of current density employed at various copper-refining works, compiled from Ulke's book on Electrolytic Copper Refining.

Various attempts have been made from time to time to further increase the current density by using mechanical means for keeping the copper from getting rough by rubbing down or smoothing the raised portions. The various processes for accomplishing this end may be classified under five headings:—

1. Revolving or moving the cathode.
2. Burnishing the copper during deposition.
3. Insulating the excrescences or growths on the copper, so as to prevent further increase.
4. Rapid circulation of the electrolyte.
5. Revolving the cathode at a critical speed (centrifugal process).

Under Class 1 may be mentioned the process of Wilde, which has for its object the deposition of copper on iron rolls for printing purposes, and patented in the year 1875. Fig. 1 represents the apparatus employed; the cathode is revolved slowly, the anodes being made from copper tubes. In this way an even thickness of deposit is obtained over the whole surface; uniform along the length of the roller, by reason of the motion imparted to the solution, which maintains an equal density of solution throughout, and uniform as to its diameter, because the rotation constantly brings fresh surfaces opposite the anodes. Additional means for securing a thorough mixture is employed by attaching a small propellor blade to a shaft run by the same machinery that actuates the cathodes. The object of rotating the cathode is to help keep the electrolyte circulated, and to ensure an even corrosion of the anode, and an even deposit of copper on the cathode. The relative position of the cathode and the anode is altered from time to time by giving the nuts holding the anodes a fraction of a turn. The current density employed is comparatively low; the operation requires many days. Figs. 2 and 3 show Cotsworth's apparatus, and Fig. 4 Wyllie's and Grant's; the former is very similar to Wilde's apparatus, the chief difference in the latter being that both anode and cathode are rotated, the apparatus consists of a vertical central rotating anode C, the iron rollers to be coated (B) rotate on their own axes by means of the gearing shown in the illustration, and are also caused to revolve around the central anode.

Class 2.—Burnishing the copper during electro-deposition is the process employed at the factories worked under the Elmore process; the burnishers are of agate, the mechanical arrangement for operating them is shown in Fig. 5, the usual current density being under 20 per sq. ft. and the voltage at the electrodes from 0·5 to 1 volt; a 4 in. mandrel is revolved at about 30 revolutions per minute.

Class 3.—Insulating the excrescences or growths on the deposited tubes is the process in which a sheepskin burnisher is substituted for an agate one, smooth deposits being obtained by the application of an insulating coating to the inequalities

* A paper read before the Faraday Society, specially revised for THE ENGINEERING REVIEW by the Author.

on the surface. The sheepskin impregnators, which move over the surface of the metal, coat all projecting parts with a thin film of animal fat, which hinders further deposition until the surrounding depressions have been raised to the common level. In later patents impregnators are mentioned composed of organic, gelatinous, or albuminous matter, free from excess of grease, rendered insoluble by treatment with bichromate, or the softening of the albuminous or gelatinous constituents of the impregnators is prevented by soaking them with a solution of formic aldehyde. It is claimed for impregnators so treated that they may be employed with equal facility in a hot or cold bath. The current used is from 35 to 40 amperes per sq. ft. of cathode area, the voltage required is about 1·6 per vat. Tubes are deposited 12 ft. in length and 16 in. diameter and ¾ in. thick, these are longitudinally cut, and opened to form sheets.

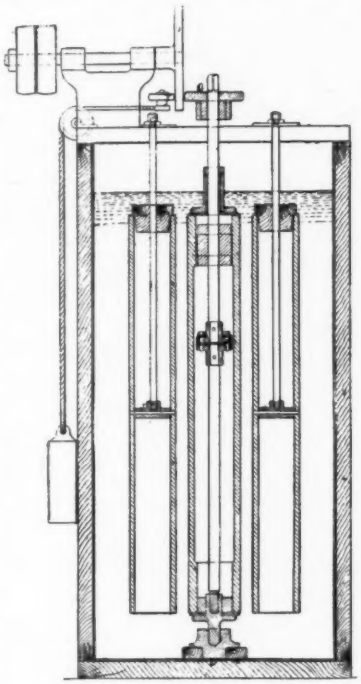
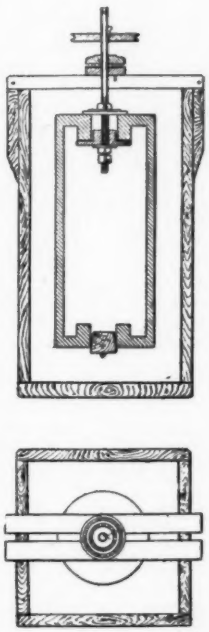


FIG. 1.—WILDE'S APPARATUS FOR COPPERING CALICO ROLLERS.



FIGS. 2. AND 3.—COTSWORTH'S APPARATUS FOR COPPERING CALICO ROLLERS.

Figs. 6 and 7 show the construction of the apparatus, the mandrel is revolved in a horizontal position, and about two-thirds of it is immersed in the electrolyte, and the sheepskin burnisher (A) is caused to travel the whole length of the mandrel by means of the mechanism shown in the illustration. It was found that if a fixed path of reciprocation be followed by the membranes or burnishers at the points where the reversal of motion takes place, rings are produced upon the cathode. To overcome this defect, the point of reversal is gradually shifted first to the right and then to the left, by means of a suitable worm-wheel and gearing, B and C are perforated plates, which are shaped to the contour of the cathode, and between which the anode metal is placed.

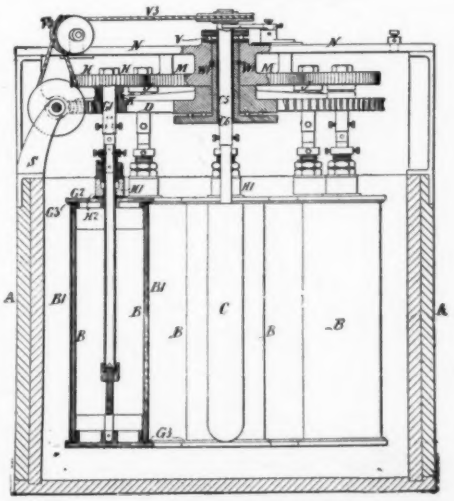


FIG. 4.—WYLIE AND GRANT'S APPARATUS.

Class 4. — Electro-metallurgists have known for a considerable time that the rate of electro-deposition can be greatly increased by rapidly circulating the electrolyte or by impinging or injecting the electrolyte against the cathode. One distinct advantage in the

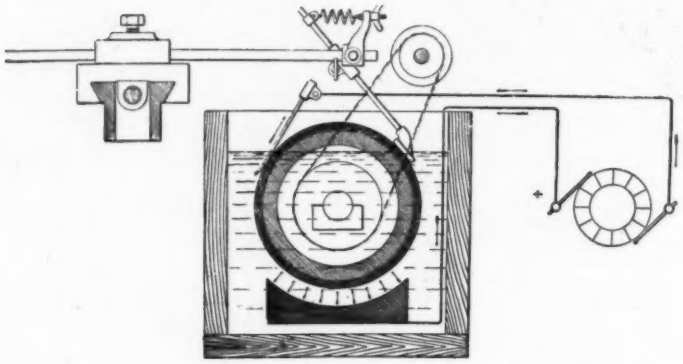
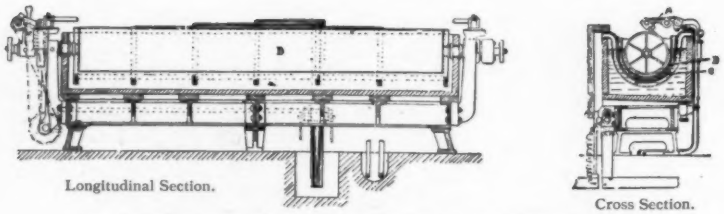


FIG. 5.—ELMORE'S PROCESS.



FIGS. 6 AND 7.—DUMOULIN'S APPARATUS, TYPICAL OF THE INSULATING PROCESS.

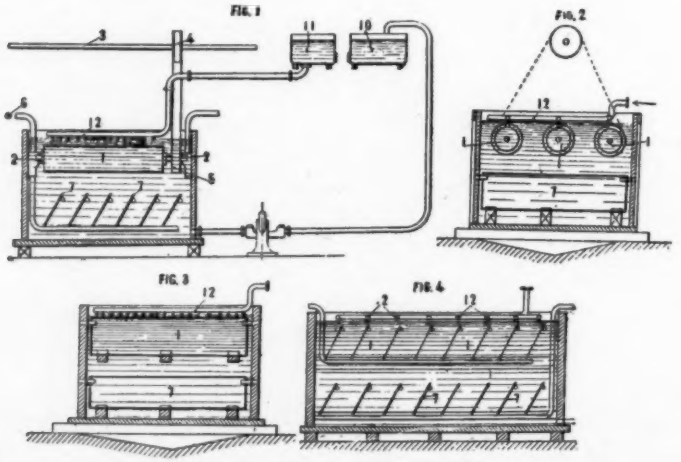


ILLUSTRATION 8.—THORFEHRN'S APPARATUS.

use of the jets is obviously to be found in the certainty that the electrolyte at the surface of the cathode is constantly and thoroughly renewed, so that a much greater current density may be employed than would otherwise be possible, and it has the advantage over processes using a mechanical burnisher that there is not the same tendency for the copper to be deposited in layers. Swan has experimented with impinging jets on revolving cathodes, and Elmore in the year 1886 took out a patent, in which he describes a process for depositing copper on revolving discs, the copper being consolidated by means of burnishers, and the electrolytic liquid forced against the surfaces of the cathodes so as to remove bubbles of gas, perforated pipes being provided for the purpose between the cathodes.

Thorfehrn, in 1893, introduced a method of depositing copper under the influence of impinging jets. The copper was deposited upon a long hollow cylindrical cathode, 8 ft. (2·4383 metres) long, and 3 ft. (91·44 cm.) in diameter, which was immersed in the electrolyte, and revolved at a low speed, whilst the copper was deposited upon it with a current density of 50 to 100 amperes per sq. ft. (9·29 dcm). During the time of depositing, numerous jets of the electrolyte were caused to play under pressure upon the surface of the cylinder (see Ill. 8). It was claimed for this process that the crystals of copper were deposited in the form of microscopic octagonal hair-like filaments, which become felted and compressed by the jets of liquid, and that the cylinders of copper, when they had been deposited an inch thick and been detached from the cathode cylinders could be rolled direct. It has also been claimed that the wires produced by this process were over 15 per cent. stronger than those prepared by the old electrolytic refining process, followed by casting, rolling, and drawing, and that the expense of such an electric refining of the metal to produce the bars required for the rolling or wire-drawing mill was $16 (£3 6s.) per ton. It is generally understood that this process, which was tried by the Anaconda Copper Refining Company, has been abandoned.

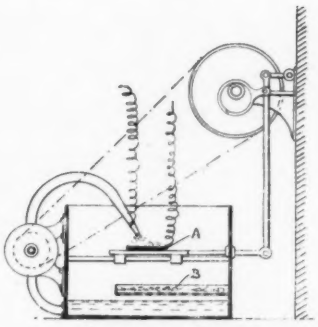
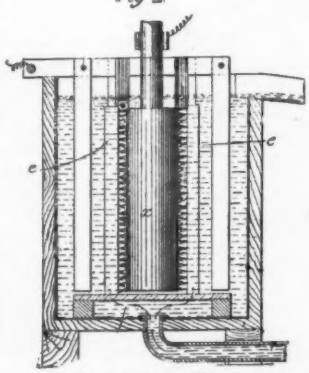


FIG. 9.—POORE'S APPARATUS.

A, Cathode. *B*, Regenerating salts.

Graham patented an apparatus in 1896, in which the electrolyte is discharged on to a flat cathode surface by means of jets, preferably from circular orifices, but when depositing on a cylinder the jets take the form of slits at right angles to the axle of the cylinder. The copper anodes, which have surfaces eight or nine times greater than that upon which the deposit is to take place, are in a spiral, gridlike, or corrugated form. The edges of the cathode are in all cases protected by a shield of vulcanite to prevent irregular deposits on the edges.

Fig 2.



Section on 4—4, Fig. 3.

Fig 3.

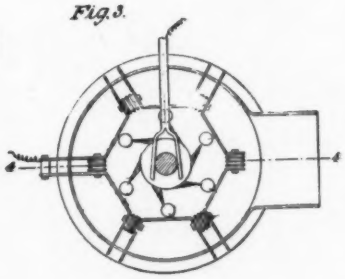


ILLUSTRATION 10. - HARRISON'S PROCESS.

a, Anode; *d*, Cathode connection; *e*, Perforated pipes; *x*, Revolving cathode.

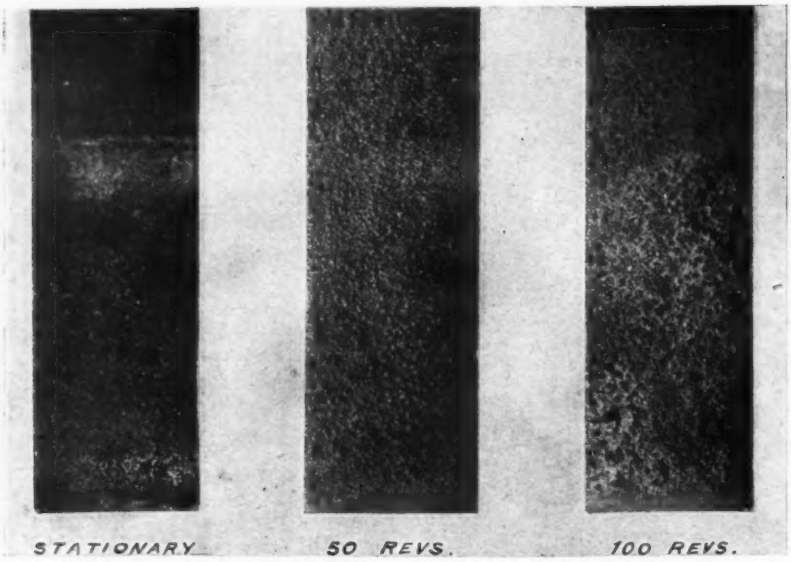


FIG. 12.

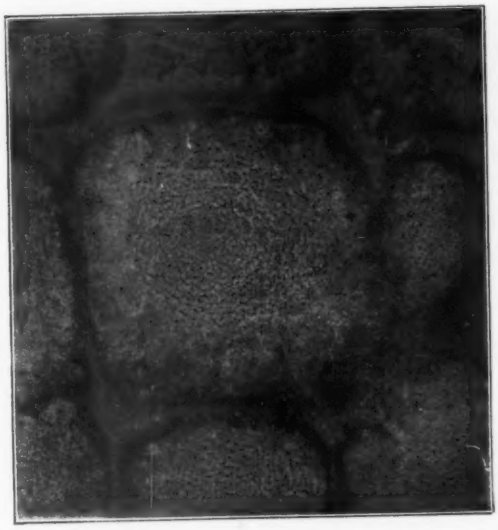


FIG. 11.—SHOWING LINES PRODUCED BY IMPINGING JETS.

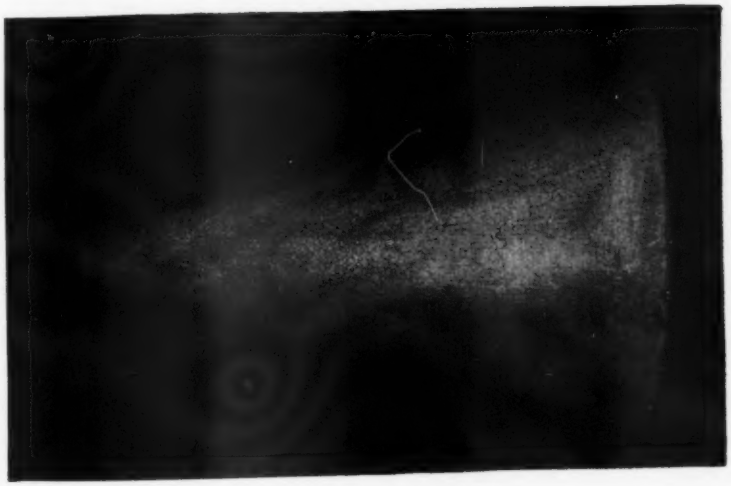


FIG. 13.—CONE ILLUSTRATING METHOD OF DETERMINING CRITICAL SPEEDS.

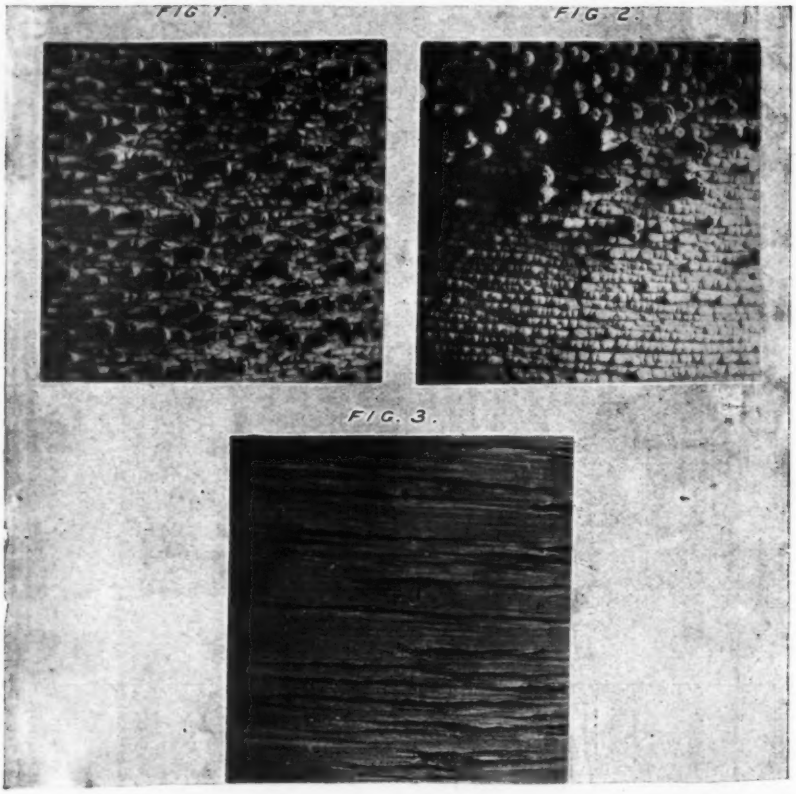


ILLUSTRATION 14

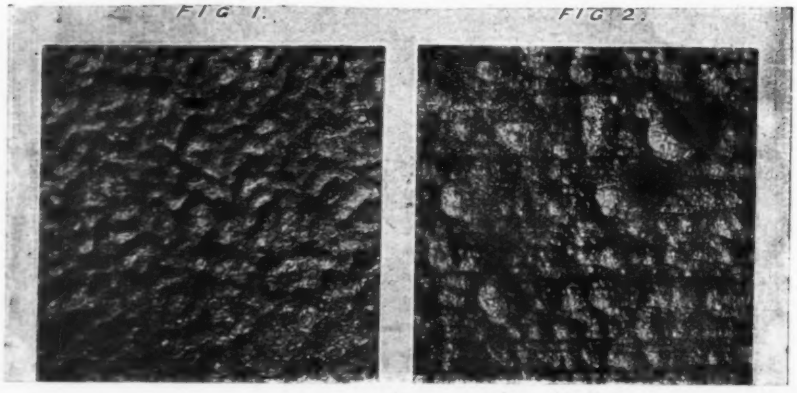


ILLUSTRATION 15.

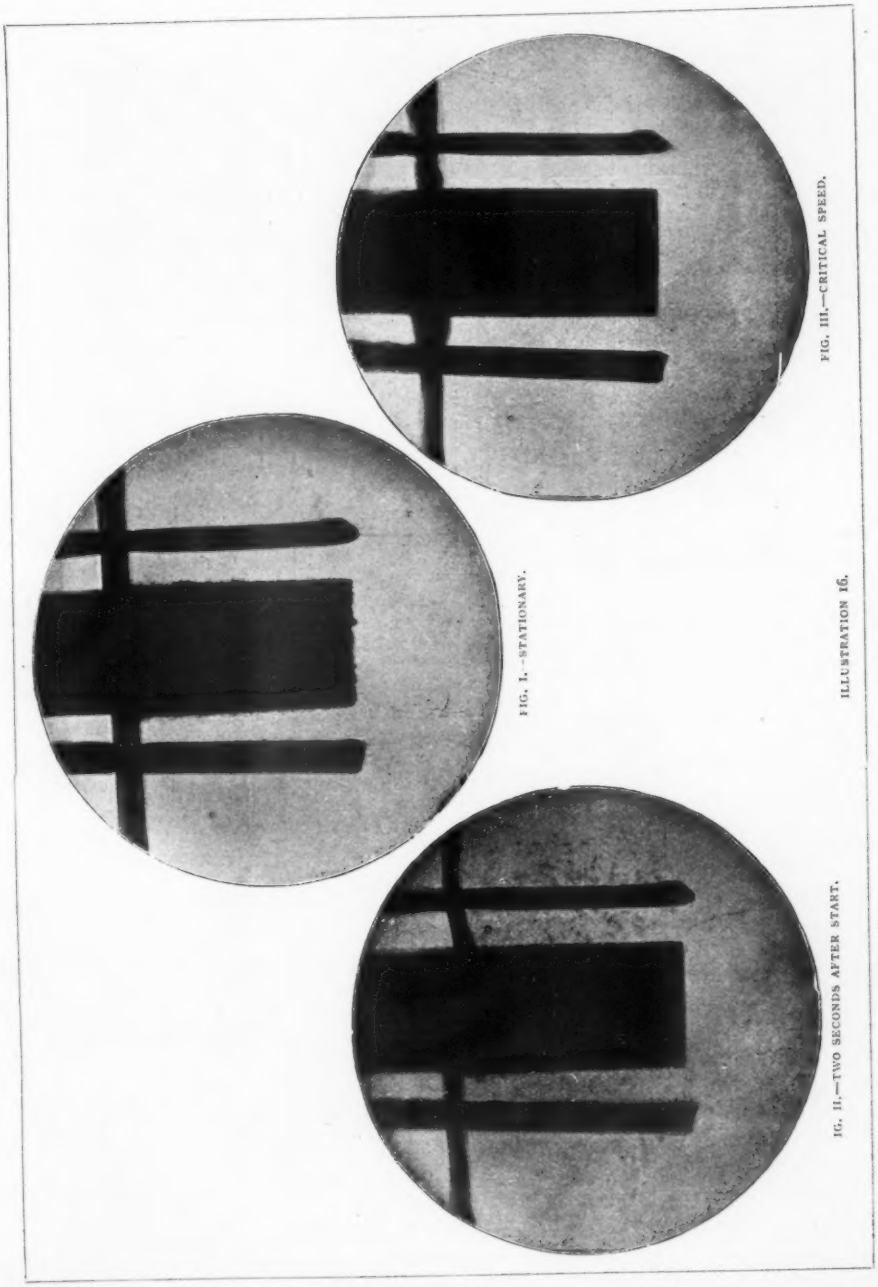
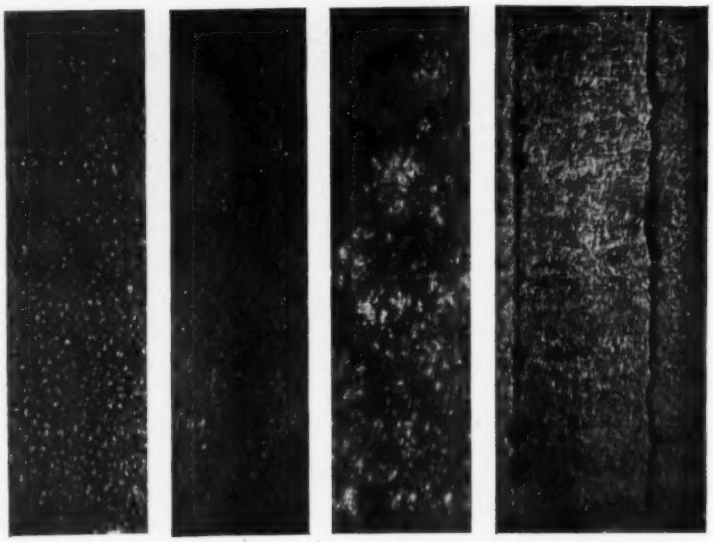


FIG. I.—STATIONARY.

FIG. II.—TWO SECONDS AFTER START.

FIG. III.—CRITICAL SPEED.

ILLUSTRATION 16.



A. B. C.

FIG. 17.—SECTIONS PARALLEL TO SURFACE OF SHEET. 70 DIAMS. MICROPHOTOGRAPHS OF COPPER DEPOSITED BY THE CENTRIFUGAL PROCESS.

FIG. 18.—FISSURE DUE TO STOPPING OF MANDREL. SECTION AT RIGHT ANGLES TO SURFACE OF SHEET. 70 DIAMETERS.

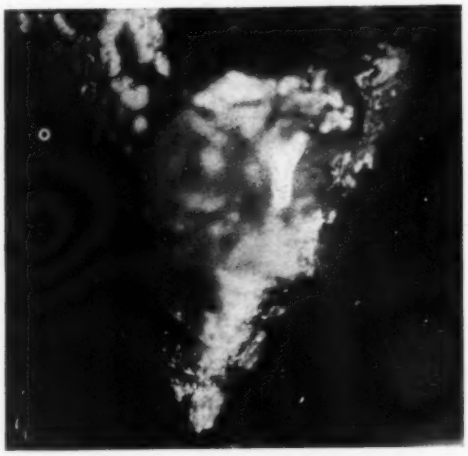


FIG. 19.—ROOT OF NODULE DRAWN FROM COPPER SHEET. 50 DIAMETERS.

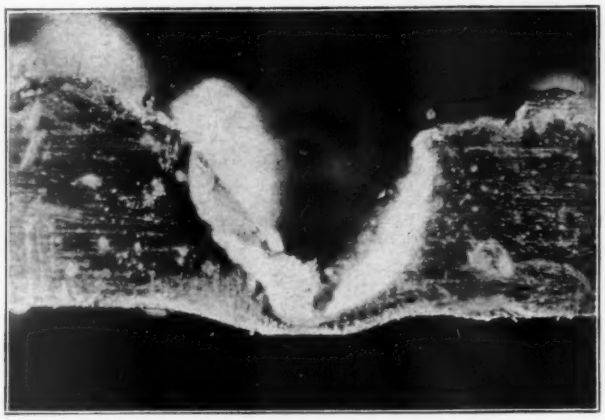


FIG. 20.—SECTION OF COPPER SHEET SHOWING CAVITY LEFT AFTER WITHDRAWAL OF NODULE. 50 DIAMETERS.

According to his specification, a nearly saturated solution of copper sulphate, containing 5 ozs. (141·75 grms.) of strong sulphuric acid per cubic foot (28·311 dcm.) of water, is used as electrolyte, and is stored in reservoirs placed at a height of from 1 to 2 ft. (30·48 cm. to 60·96 cm.) above the electrolytic tanks, thence it is conveyed to $\frac{3}{8}$ in. (0·95 cm.) jets that deliver it in a stream upon the surface of the cathodes, which are placed at a distance of 1 in. (2·54 cm.) from the orifices of the jets. It is stated that a current of 300 amperes per sq. ft. (9·2 sq. dcm.) may be employed with safety at all points within the sphere of influence of the jets, beyond this area it is obvious that the deposit would be pulverulent and useless. The radius of the protected area was found to be 5 in. (12·7 cm.) so the number and disposition of jets employed must be arranged accordingly.

Poore, in 1896 obtained a patent for an apparatus for depositing metals, as shown in Fig. 9. The solution is sprayed, or otherwise delivered, over the cathode plate A, which may be an electrotype, and thus the stream or jet forms the only connection between the anode and the cathode. The cathode may be agitated by the table (upon which it is mounted) being moved to and fro by the eccentric arrangement shown in the illustration. On the tray B is placed the required salt to bring the electrolyte up to strength for re-use.

Dessolle worked for many years in Paris a process, which was patented in England in the year 1899, for coppering ornamental ironwork and statuary, in which the solution is caused to impinge against the object to be coppered, to remove the gas bubbles from undercut portions.

The latest impingement process is Harrison's process, the details of which will be readily understood by reference to Fig. 10.

The rapid deposition of copper by impingement of the electrolyte is not likely to be applied commercially until the amount of solution required to be circulated per sq. ft. of cathode can be greatly reduced. With a current density of 100 amperes per sq ft. (9·29 sq. dcm.) it is necessary by the ordinary impingement process to circulate about 10 gallons (45 litres) per minute per sq. ft. of

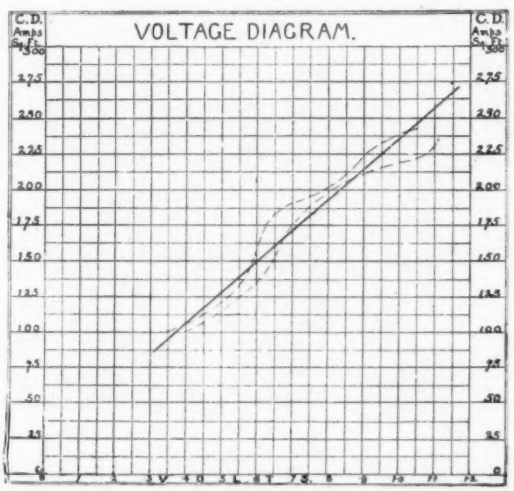
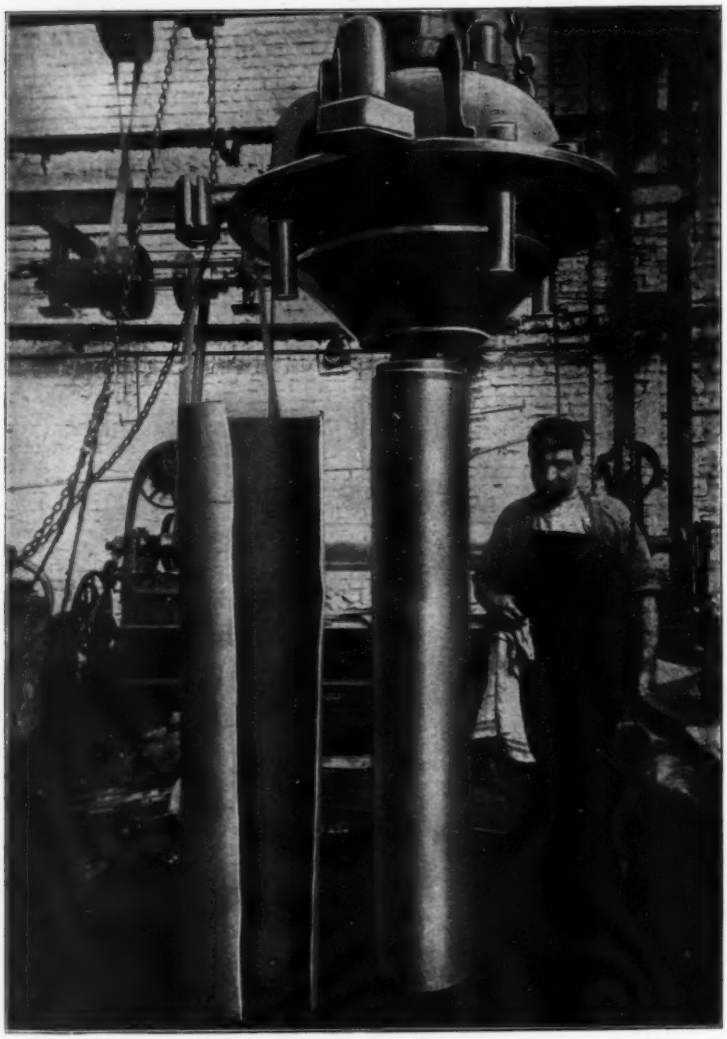
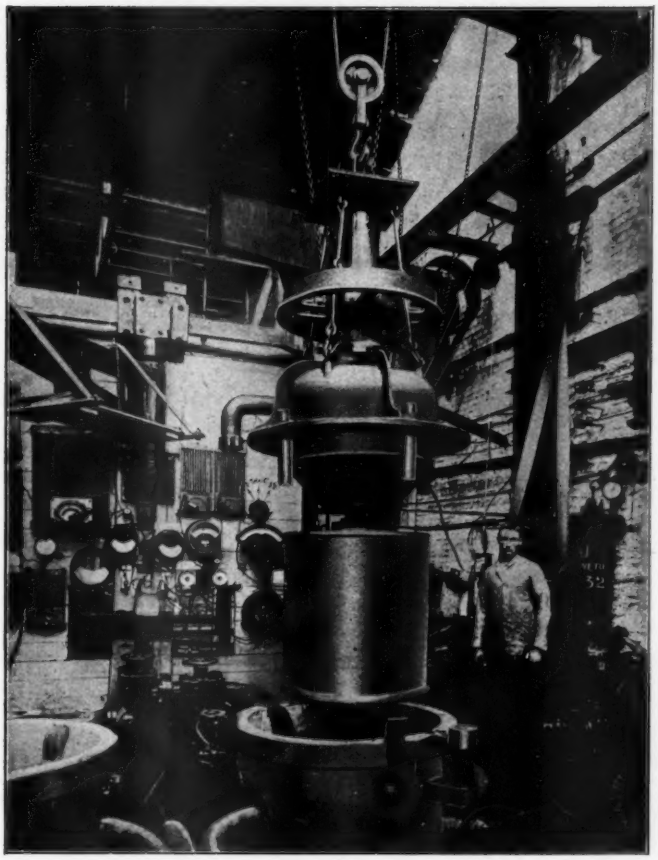


FIG. 21.



Tube Mandrel.

FIG. 22.—CENTRIFUGAL PROCESS.



Sheet Mandrel.

FIG. 23.—CENTRIFUGAL PROCESS.

cathode surface, and unless the jets are continuous, and the cathodes revolved, a rough deposit is obtained. To obtain smooth deposits of copper by an impingement process it is essential that the solution be free from air, otherwise the deposit of copper is rough, and is deposited in the form of annular rings, as shown in Fig. 11, which is a photograph of a lead plate coated with copper by an impingement process at a current density of 160 amperes per sq. ft. (9·28 dcm.), temperature 50° C., the electrolyte being forced at a pressure of a few pounds through a lead box bored with $\frac{1}{8}$ in. (0·31 cm.) holes at a distance of 1 in. (2·34 cm.) apart from centre to centre.

Class 5.—The author when carrying out experiments on the electrolytic production of copper tubes, which should be free from laminations, observed that if the mandrel constituting the cathode was revolved at a certain circumferential speed, smooth thick deposits of copper could be obtained at very high current densities which could not be obtained by any other method. Further investigations were made to determine the

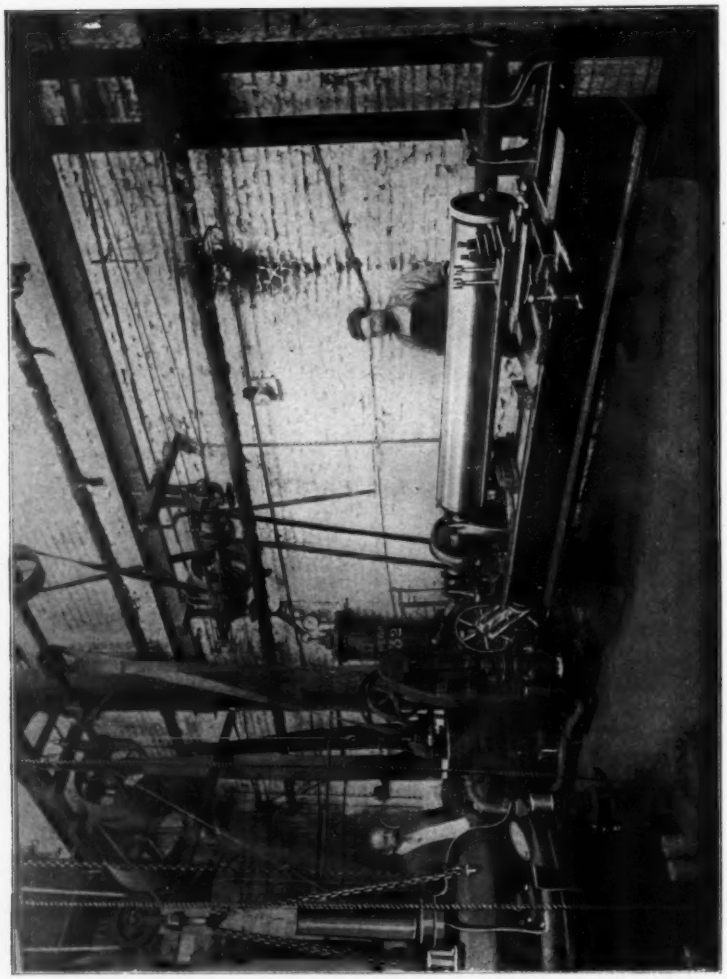


FIG. 24.—METHOD OF EXPANDING OFF TUBES.

speed, and Fig. 12 shows the effect of increasing speed, every other condition being constant. The method eventually adopted for determining the critical speed required under varying conditions was a cathode in the form of a cone, as shown in Fig. 13, by which means the critical speed can be determined very readily. It has been found that the tensile strength of the copper increases with the speed of rotation.

Fig. 14 shows three typical copper deposits obtained on revolving mandrels before the critical speed is obtained.

It is found that very pure copper is obtained by the centrifugal process, even when very high current densities are employed, and the solution contains much

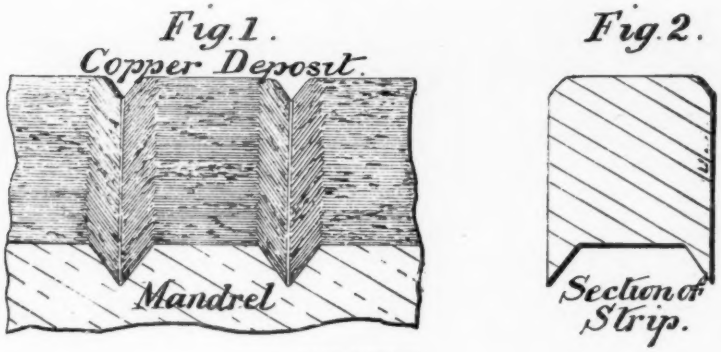


ILLUSTRATION 25.

foreign matter in suspension, as shown by the following analysis of a copper sheet :—

	Percentage.
Iron	0·0189
Arsenic	0·0015
Lead	0·0013
Antimony	0·0010
Bismuth	0·0008
Silver	Absent
Nickel	Absent
Sulphur	Absent
Copper, by difference	99·9765

The composition of the electrolyte usually employed is copper sulphate 10 per cent., sulphuric acid 10 per cent., water 80 per cent.

In the ordinary process of copper refining, when a current density of about 17 amperes per sq. ft. is employed, the copper is deposited in the form shown in Fig. 15: (2) the reverse side of the cathode which becomes anode in the series process is shown in (1). The top of the nodules or excrescences form ledges on which the impurities in suspension settle and become ultimately sealed by the further deposition of copper, the circulation of the electrolyte not being sufficient to sweep them away, this difficulty is overcome in the centrifugal process as shown in Fig. 16, which is a reproduction of photographs of a revolving cathode and two anodes thrown on a screen. No. 1 shows the mandrel stationary; No. 2, the mandrel immediately after starting to revolve; the air bubbles which were adhering to the mandrel can be seen being dissipated. No. 3 shows the mandrel running under normal conditions at critical speed. By watching the process in operation on a screen it will be observed when any particles of impure metal detach themselves from the anodes and gradually approach the cathode, as soon as they arrive within a certain zone of the cathode they are immediately repelled by the centrifugal action.

Another great advantage of the centrifugal process is that the copper is free from lamination, such as is found when copper is burnished at stated intervals; this point has been established both by mechanical tests and microscopical examination. In the latter case specimens were cut from three samples (Fig. 17 A, B, and C), and were polished, etched and photographed; in all cases the metal was close and homogeneous, and free from gaps, pits, and fissures.

It has been found that any stoppage or great variations in the speed of the mandrel causes lamination. This point is clearly shown in the microphotograph, Fig. 18. The nodules or excrescences that form on copper are nearly always due to a particle of dirt settling on the cathode or a bubble of gas adhering tenaciously, with the result that the copper builds up around the adhering substance, rapidly increasing in size, as shown in the microphotograph, Figs. 19 and 20.

Fig. 21 shows curves of the actual voltage employed for varying current densities, and Figs. 22 and 23, the apparatus employed for the centrifugal process, the mandrel being provided with Pelton Wheels, which are driven by the electrolyte impinging against them; Fig. 24 shows the method of expanding off the tubes by passing over the surface a rounded roller.

Copper tubes produced by this process without any drawing have been given a maximum stress of 17 tons, and a tube, after drawing, has stood a pressure of

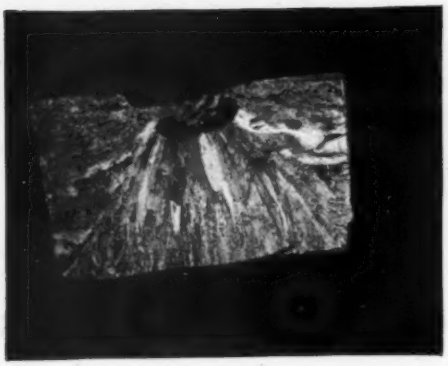


FIG. 26 (1).

3,000 lbs. per sq. in. (thickness of metal 0·063 in.) without showing any signs of distress; and sheets, without rolling, have given a maximum stress of from 28 to 34 tons (2,000 lbs.) per sq. in.

The production of copper wire by electrolytic means is a more difficult problem than the production of copper tubes and sheets. Various processes have been suggested and tried from time to time, such as electro-depositing copper on a thin copper wire until it has attained a considerable thickness, and then drawing the thickened wire down again to a comparatively fine wire. Swan and Sanders have both experimented with such processes, but so far they have not been worked commercially.

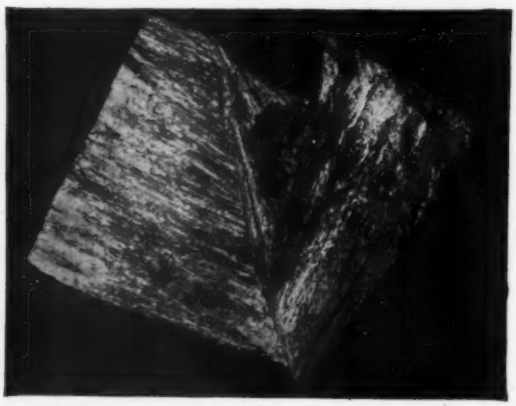


FIG. 26 (2).

Elmore's process consists of producing copper tubes by his burnishing process, and cutting them up in long spirals; such a process is very costly, and the wire when finished and subjected to a torsional test is very unsatisfactory. Other experimenters have tried placing insulating strips on a cylindrical mandrel so as to produce long copper spirals; the spirals thus produced are uneven and unsuitable for drawing down to wire on account of the roughness formed on the edges. The method employed in conjunction with the centrifugal process consists in making on the mandrel a spiral scratch; the effect of this scratch, which must be angular, is to affect the molecular structure of the copper and to form a cleavage plane as shown in Fig. 25; if the scratch is not angular but round at the base, the copper will not divide. The line of cleavage is no doubt formed in the same way as a cast metal as shown in Fig. 26, (1) being a sample of antimony sulphide cast in a rectangular mould, and (2) a sample of zinc, also cast in a rectangular mould. In each case the line of cleavage can be clearly seen; if the mould has rounded corners the crystalisation would be radial, and there would be no cleavage plane. The crystalline structure of the deposited copper has a line of cleavage starting with the sharp point of the scratch on the mandrel. The copper separates more readily if unwound at an angle to the axis of the mandrel, as shown in Fig. 27. The construction of mandrel capable of making three or four miles of wire in one operation in a few hours from crude copper is shown in Fig. 28; the vat is annular in construction, the mandrel being 7 ins. in diameter, and making about fifty revolutions per minute. A great feature of such a vat is that there are no working parts in the electrolyte, and no stuffing boxes or glands.

The capital expenditure on plant required for the centrifugal process compares very favourably with an up-to-date rolling mill and wire drawing plant; the cost of such a plant with buildings and engines, is about £80,000 for an output of about 100 tons per week, or 5,000 tons per annum.

The following are some of the chief advantages claimed for the process: The copper is refined and manufactured into sheets or tubes in one operation, the copper being of a hard nature, similar to that

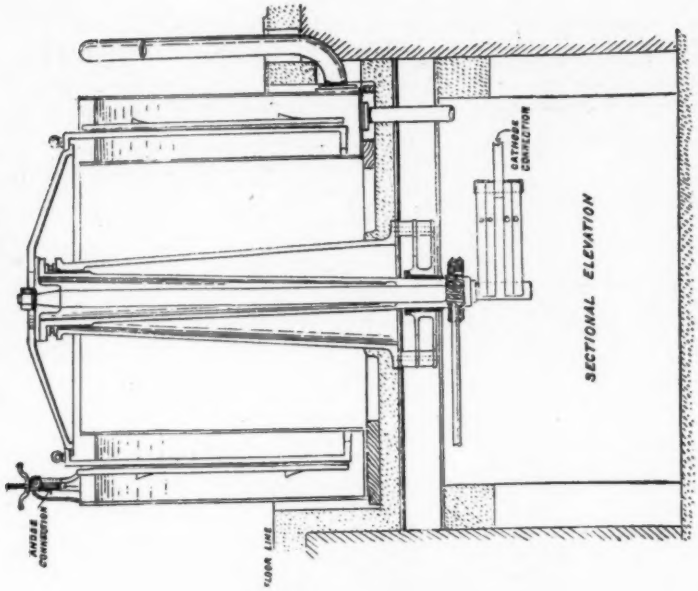

DEPOSITING VAT
FOR CENTRIFUGAL COPPER PROCESS
SECTIONAL ELEVATION
CATHODE CONNECTION
ANODE CONNECTION
FLOOR LINE

FIG. 28.

FIG. 27.

which is cold-rolled; the process is at least ten times faster than any existing electrolytic process, a high current can be employed without deteriorating the quality of the copper, there is no risk of lamination, as no burnisher is employed, the plant is simple and free from mechanical complications, the amount of copper locked up for a given output is small compared to other processes; finally, anodes of very impure copper can be used as compared to the anode copper used in other systems.

In conclusion, I should like to acknowledge my indebtedness to those who have worked so hard and with so much enthusiasm during the years it has taken to develop the centrifugal process. The work at times has been of a most arduous character, and to obtain the data required it has been necessary to run the plant continuously, day and night, for long periods.

Comparative Data of Copper-Refining Works.

Name of Works.	Max. capacity in lbs. and kilos per day per h.p.		Terminal voltage.	Current density amperes per sq. ft.	Current density amperes per sq. dcm.	Tank capacity in cub. ft. per lb. of copper per hour.	Tank capacity in cub. dec. per gramme of copper per hour.
U.S.A.	lbs.	kilos.					
Raritan	100	45·359	0·37	15	139·35	7·1	0·443
Anaconda	126	57·153	—	10—20	92·9—185·8	10·1	0·63
Guggenheim	144	65·317	0·3—0·4	10	92·9	7·0	0·437
Baltimore	170	77·111	—	—	—	—	—
Nichols	—	—	0·1—0·2	—	—	5·3	0·331
Great Falls	—	—	—	30—40	278·87—371·6	—	—
Balbach	125	56·699	—	12—16	111·48—148·64	—	—
England.							
Bolton (Fryhall)	60	27·215	0·7—0·8	12	111·48	11·1	0·693
Leeds (Elmore)	26	11·793	—	—	—	8·75	0·546
Germany.							
Hamburg	165	74·843	0·45	1·85	17·186	—	—
Oker	118	53·524	—	—	—	—	—
France.							
Biache St. Vaan	110	49·895	0·2	3	27·87	—	—
Marseilles	110	49·895	0·2	1·24	11·52	—	—
Russia.							
Halakent	44	19·958	0·34	3·7	34·373	43	2·683

Internal Combustion Engines.*—III.

By DUGALD CLERK, M.Inst.C.E.

I now propose to take up first the Clerk cycle and its modifications, the Koerting and Oechelhauser, and then the constant pressure engines, like the Brayton and the Diesel, and other engines of that type.

The Clerk cycle engine is not so well known to-day as it was more than twenty years ago, so I think it desirable to describe it with reference to Fig. 20, which is a sectional plan. In the Clerk engine the motor cylinder had, at the front end, large ports leading into an annular space, these being the exhaust ports. The compression space was conical, and the charge was sent in by means of a separate pump, which I called the displacer. The action of the engine was as follows:—When the piston got to the out end of its stroke, and the crank was crossing the out centre, the piston over-ran the exhaust ports on the out-stroke, and covered them on the in-stroke. Meantime the pump, or the displacer piston, which was attached to a crank at right angles in advance of the main crank, was sweeping in and giving its charge a slight compression. That charge passed through a connecting pipe, and through a check valve, into the conical end; displacing before it all the contents of the cylinder. When the main crank had returned about 40 degrees of its circle under the centre, these ports were closed. It opened about 40 degrees above and closed 40 degrees under, and in that time the displacer piston had gone fully in and discharged its charge into the cylinder and combustion space through the lift valve. Then the motor piston compressed the charge, and ignition took place at the end of the stroke, just as in the Otto cycle. The object of the invention was to enable one motor cylinder to give an impulse at every revolution. In the Otto cycle there is only one impulse for two revolutions, so far as the main cylinder is concerned. The Clerk engine gave one impulse for every revolution of the main crank in the main cylinder, but, to make that possible, it was necessary to provide an auxiliary crank and displacer cylinder. The idea was, of course, to diminish the irregularity of the Otto cycle by having an impulse at every revolution, or more frequently, that is to say, two impulses per revolution, obtained by making the engine double acting. The object was to get very much more power for a given weight of engine, as the pump was light and only required to deal with its charge at a low pressure. In construction the engine was a very simple one.

Fig. 21 compares the diagrams obtained from the Clerk and the Otto cycles. In the four-stroke cycle diagram there is clearly seen the charging stroke, the compression stroke, the explosion and the expansion, and then the point of opening the exhaust valve and exhausting the burnt gases. In the two-stroke, or Clerk diagram, there is nothing shown upon the main indicator card of the charging stroke, because immediately the piston over-runs the exhaust ports the pressure falls almost to atmosphere, and then the displacer piston at right angles in advance of the main crank discharges its charge into the cylinder while the main crank is crossing the centre. Compression of the charge then takes place, and ignition, expansion, and exhaust follow as I have described.

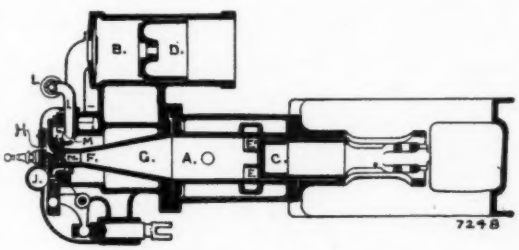


FIG. 20.—SECTIONAL PLAN OF CLERK CYCLE ENGINE.

In the Clerk cycle engines the considerations which govern power and economy very closely resemble those of the Otto cycle, but there are several points which require to be carefully considered—points,

* Abstract of a lecture before the Society of Arts.

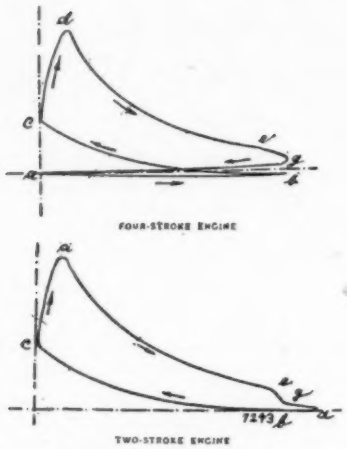


FIG. 21.—COMPARATIVE INDICATOR DIAGRAMS FROM ENGINES WORKING ON THE CLERK AND OTTO CYCLES.

indeed, of considerable difficulty — with regard to which the Otto cycle is a far easier cycle than the Clerk cycle. In the Clerk cycle, the charging has to be accomplished in the motor cylinder, while the crank is passing through an angle of about 80 degrees. Sometimes a little larger angle is allowed, but, roughly, 80 degrees of the crank angle is the limit for charging of the motor cylinder. Because of this, much larger inlet valves, and very much larger discharge areas, are required in the Clerk than in the Otto cycle. In the Otto cycle the charging stroke occupies not only the whole of one stroke, which amounts to 180 degrees of the crank movement, but, in addition, a further 40 degrees, which permits the inlet valve to be held open considerably over the out centre, and also to be opened a little before the centre on the in-stroke. In consequence, the Otto type of engines allows three times the time interval to charge the cylinder, at a given rate of revolution, that it is possible to allow in the Clerk cycle. For a given valve area, the velocity of charge entrance in the Otto cycle is about a third of that in the Clerk cycle. This means that the Clerk cycle engines are more difficult to charge, and require greater power expenditure to charge the cylinder than the Otto cycle. That is the great weakness of the Clerk cycle as constructed at present.

Then there is this further point. In the Otto engine, when the piston moves out, taking in its charge, there is no question of any possible discharge at the exhaust ports, because the piston is sucking in the charge by a partial slight deficit of atmospheric pressure, and there is no exhaust port open through which fresh charge may be lost. In the Clerk cycle, the proportions of displacer and motor cylinder have to be very accurately ascertained, otherwise part of the charge entering the cylinder is apt to pass right down through the centre of the exhaust gases which are being displaced, and pass out of the exhaust port. That was overcome in the early Clerk engines by the peculiar conical shape of cylinder end, which has been since consistently adhered to in all the engines operating on the Clerk cycle. That difficulty, however, is met in two ways. One way is to put in a smaller charge than in the Otto cycle, but that has the disadvantage of leaving too much exhaust gas, and also giving you a smaller power of engine. Consequently, every designer of the Clerk cycle engine attempts to get in the full charge. The best method is to send into the cylinder, first a good heavy charge of air to displace the exhaust products, and then to follow it with a somewhat strong charge of gas and air. That is what I did in 1881, and that is what is being done to-day in all the large gas engines. That, however, is a somewhat difficult thing to do. The consequence is that if one of these cylinders be charged as fully as it would be in an Otto cycle, a slight proportion of gas is lost at the exhaust ports, and although in a small engine, with a comparatively light load, the economy very closely approaches the best Otto economy, yet the maximum efficiencies that are possible with the Otto cycle have not been obtained with any two cycle engines. Because of this, the Clerk cycle has been reserved for somewhat special uses. It has come into extensive use of recent years in connection with large blast furnace gas engines.

The modern representative of the Clerk cycle engine is known as the "Koerting" engine, a German production, but so far as its essentials are concerned, it was invented in England twenty-three years ago. The engine is shown in Fig. 22. The charge is admitted at the inlet valves placed at the conical ends of the cylinder, and instead of having one pump for gas and air mixed, two pumps are provided, one of which is for gas, and the other for air. This engine, instead of being single-acting, as the Clerk engine was, is double-acting, so that, so far as the main crank is concerned, there are

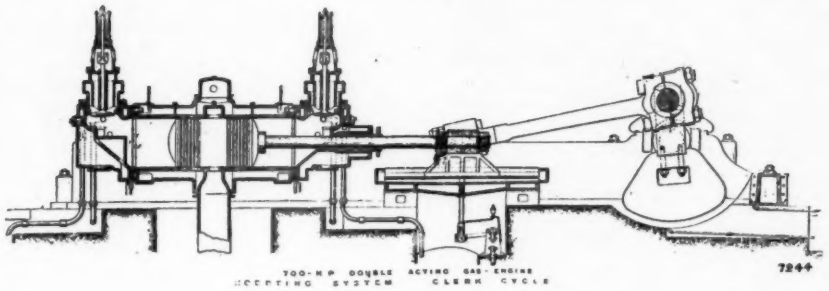


FIG. 22.

two impulses every revolution just as there are in a steam engine.

In this Koerting engine, the piston in the position shown is over-running the exhaust ports at one end of its stroke, allowing the pressure in the cylinder to fall to that of atmosphere.

Fig. 23 is the diagram of the engine, showing the fall to atmosphere just at the point where the piston over-runs the ports. Then, immediately the pressure has fallen to atmosphere (this requiring about 20 degrees movement of the crank), the charge inlet valve is opened and air is first pumped in from the air pump. After the air has been flowing in for some little time to throw the exhaust gases forward, the gas is pumped in from the same valve, so that no mixture is made until the gas and air mixture enters the cylinder. That is a very important point. In a small engine the gas and air may be mixed in the pump, but in a large engine the charge of gas and air must be mixed just as it enters the cylinder. In a small engine an occasional back ignition into the displacer is no great matter; in a large engine it will be a serious matter; so that in the large engine the gas and air are kept separate until they flow into the motor cylinder. When the charge has entered, air first, and then gas and air, and has displaced the exhaust products, the piston is closing the ports which shut off the exhaust after a movement of about 40 degrees of the crank; the compression then proceeds, and ignition and expansion take place, so that an impulse is obtained at every forward stroke behind the piston, and at every backward stroke in front of the piston. If it were possible to charge the cylinder with absolute certainty, without any chance of loss at the exhaust, there would be a great deal to be said for this cycle, because it undoubtedly gives a very powerful engine for a comparatively light weight, and in very large engines the question of economy is not the pressing question. In addition to the difficulty of charging the Koerting engine, due to the fact that the cylinder can only be charged through a small crank angle, there is a further difficulty due to the fact that, for a given flame temperature there are double the number of flame impulses upon the piston in a given number of revolutions. The effect of this is that, in the Otto cycle, although there may be a watered piston, still it does not matter whether the piston is watered or not, or whether the jacket is watered or not; but in these large engines the terrible flow of heat through the side walls causes, undoubtedly, a severe strain on the metal. In the Otto cycle, all the metallic parts which have been highly heated by an explosion. have a rest of a fraction of a second, which, it is true, is not very much in an engine of 160 revolutions—it is about one-sixth of a second—between one explosion and the other. In the Clerk cycle engine the metal has no such rest; immediately the one explosion has finished, the new charge is put in and compressed and exploded again, so that the metal is strained somewhat more than on the Otto cycle, although that is not found to be a very serious point.

Now, in addition to the Koerting engine, there is another engine somewhat on the same lines; that is, an engine in which the exhaust gases are displaced through ports in the side of the cylinder by the entering charge. In the Oechelhauser engine shown in Fig. 24, that is what is done. It is a very interesting engine, and it runs with great smoothness. The engine has two opposing pistons, driven from a crank in the front part of the engine; there are three crank pins, one, the main crank pin, driving the front piston; then, outside of that, there are two other crank pins, disposed exactly opposite, that is, 180 degrees from the

main crank. These two opposite pins drive separate side rods and cross-head, and the two pistons therefore move out at equal velocity. This arrangement produces a very nicely balanced engine, all the strain of the explosion being removed from the frame, and taken by the cranks only. The two pistons over-run the ports, the one at one end, and the other at the other. In the front end, the piston over-runs the exhaust ports, and the pressure falls to atmosphere exactly, as it does in the Clerk and Koerting engines. A little later the back piston is over-running the air ports, shown in Fig. 24 as a series of holes. The air is accumulated by means of a pumping arrangement, and this air first runs into the cylinder from ports placed all round it, driving out the exhaust gases. In this way the cylinder is cleared of the hot incandescent matter before the gas enters. Then, as the piston moves further back, the next ports are uncovered, and the gas enters, coming from a separate reservoir. The mixture of gas and air runs right up to the cylinder, and discharges the exhaust gases and the air that has been put in first; then compression takes place, and then ignition, expansion, and so on, just as in the other cycles. The engine illustrated is a blowing engine for a blast furnace, the blowing cylinder being directly coupled on to the piston rod. This engine has one great advantage over other forms of engine working on the Clerk cycle, viz., that there are no valves, so far as the combustion and explosion is concerned, except the pistons themselves. The two pistons form the whole of the valve arrangements, and no pressure of explosion can come on any other valve. There are no lift valves exposed to the consequences of an explosion, so that a very large valve area may be allowed. The engine, however, has disadvantages. It is a more expensive engine to build, and a very considerable weight of metal is required for a given power, but it is a very smooth-running engine, and, although it does not come up quite to the Otto cycle in economy, it has given great satisfaction in Germany, and is, I believe, running very well in England from the point of view of requiring but little repair. The well-balanced pistons, and the fact that only wide open ports are over-run by the pistons, make it eminently suitable for gases such as blast-furnace gas, which would always carry a slight amount of dust with it.

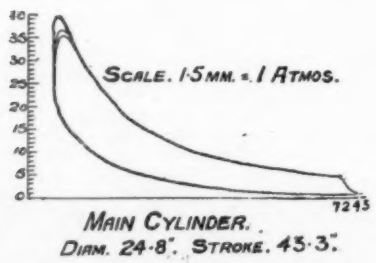


FIG. 23.—DIAGRAM FROM THE KOERTING ENGINE.

Another modification of this type of engine is found in the Day engine, which was produced many years ago: it was called a valveless engine. In this engine the front end of the cylinder and the crank was enclosed in a casing, very much like the modern petrol engine, and the front end was used to take in charge which was to displace the exhaust products at the back. The consequence of that arrangement was that you could run the engine with an impulse at every revolution without the displacer. Many engineers in America have taken up that particular modification of the Clerk cycle, and it is very commonly used for small launches and marine work, but one often sees in motor and other papers that great surprise is expressed that more power is not obtained from an engine of the type. The reason is clear. If the piston of an engine displaces only its own volume of charge into a comparatively large space, when the clearance is great and the pressure in that space falls, the whole of the contents of that space, owing to the large clearance, cannot possibly be discharged, and only about two-thirds of the piston stroke charge passes in behind the piston. The consequence is that we have a charge which is one-third less than the Otto charge, and a larger proportion of the exhaust. This makes it necessary to use lower compressions in order to avoid pre-ignition. The general effect of that cycle is that instead of getting, as in the Otto cycle, a mean pressure in a small engine of 80 lbs. on the square inch, not more than say 45 to 50 lbs. is obtained, and then, although there is an impulse every revolution, nothing like double the power of the Otto cycle is obtained, and the front casing must be made heavier. If any engine is to give the full average pressure possible, some device such as I have used, to give the full charge, must be provided. This may be done on the Clerk cycle with a displacer, because the displacer may be regulated as desired, but it cannot be done in these little American engines.

I have now run quickly through the different points of the Clerk cycle—that is, the points wherein that cycle differs from the Otto. So far as the ideal efficiency is concerned, the formula given in the first lecture holds for the Clerk cycle as well. The only difference is that the difficulties in keeping down the temperature of the charge are much greater in the Koerting and Clerk cycle than in the Otto.

In dealing with the constant-pressure engine, it will be well to bear in mind the formula, now well established, for the ideal efficiency of the constant-volume engine—that is, the Otto cycle and the Clerk cycle—in the case where expansion is carried to the volume occupied by the charge before compression. The efficiency of engines of that type is:—

$$E = 1 - \left(\frac{1}{r}\right)^{\cdot 408}$$

In the constant-pressure cycle, where expansion is carried to the same pressure as before compression, the ideal efficiency is given by the same formula. In the Diesel, or the constant-pressure cycle, where expansion is not carried to atmospheric pressure, the efficiency is different, it is as follows:—

$$E = 1 - \frac{T_1 - T_0}{1{\cdot}408\,(T_x - T_c)}$$

In this formula, which I worked out some little time ago, T_0 is the temperature of the charge before compression; T_c is the temperature on compression; 1·408 is the ratio of the specific heats; T_x is the maximum temperature of combustion; and T_1 is the temperature at the end of the expansion. In this case there is a much more complicated formula than the formula in the constant volume cycle. Diesel started with some erroneous notions as to what he was going to do; his idea was that he was going to follow the Carnot cycle. In the Diesel engine the piston takes in just as on the Otto cycle (it can work on that cycle, or on any other cycle), a charge of air only—not gas and air, but air only. It compresses that charge up to a pressure of about 500 lbs. per square inch. At that pressure the temperature of adiabatic compression is so high, something in the neighbourhood of 700° C., that any oil injected into the cylinder with air at once ignites without the use of any outside igniter. Diesel thought he was going on the Carnot cycle, but what he, in fact, did, was to get the advantages of the constant-pressure cycle without the danger of pre-ignition or explosion or compression by having air in the cylinder only. Of course, it is impossible to pre-ignite, because there is nothing to burn in the air. Oil and air were added by means of a sprayer when the compression was complete, the air being previously compressed to about 150 lbs. to the square inch above the pressure in the cylinder, that is to say, 650 lbs. On injection of the oil, ignition takes place and then expansion.

In his description of the engine which he called a rational heat motor, Diesel suggested that other inventors or designers of engines were proceeding upon wrong principles, and that the right principle was to rise to the maximum temperature by compression, add heat at the maximum, and have no increase in temperature after your compression. In his first engine, he thought he had done that; but it is obvious that if it is desired to follow the Carnot cycle, instead of having a pressure of about 50 atmospheres to get the maximum temperature used in this engine, a pressure of about 200 atmospheres is required. That, of course, means that heat must be added on the expanding line. Working on the Carnot cycle, an extremely slender diagram is obtained, and an enormously heavy engine is required. Diesel did not notice what has recently been noticed, that the efficiency of the Carnot cycle, constant volume, and constant pressure engines are all exactly the same if you have the same compression. The consequence is, that you gain nothing by going to the Carnot cycle. Diesel, in some of his recent papers, still adheres to the idea that he is dealing with a modified Carnot cycle, but all heat engines may be considered as modified

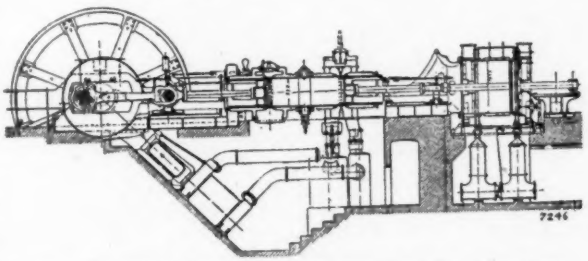


FIG. 24.—SECTIONAL ELEVATION OF OECHELHAUSER GAS BLOWING ENGINE

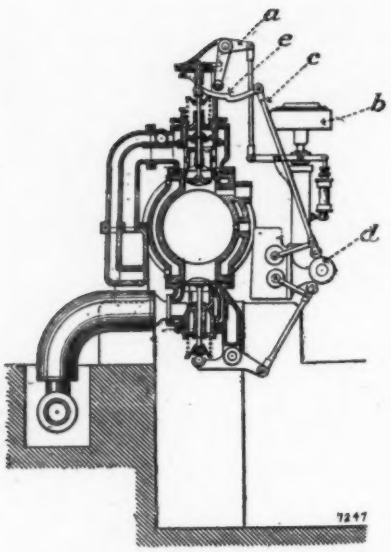


FIG. 25.—SECTION OF VALVE BOX DEUTZ GAS ENGINE.

Carnot cycles, one as well as another. Twenty years ago I was in the habit of drawing Carnot cycles, and of cutting out a slice to represent any given engine. If you take the Carnot cycle, and take the compression curve, and take a vertical line for heat addition, you have the constant-volume engine. If you take the Carnot cycle, and add heat along a horizontal line, you have a constant-pressure engine. You can carve out of the Carnot cycle any engine you like. but you must not say, when you have carved an engine to suit your own convenience, that you are now working a Carnot cycle, and that the engine is therefore different from any other. What Diesel has, in fact, done is to use very high compressions on the constant - pressure cycle, on the formula which I have given above. Many attempts have been made to carry out constant-pressure engines for gas. Diesel has tried them. I myself built an engine in 1887, a diagram from which is reproduced at Fig. 19 (see previous article). This was a constant - pressure engine, or a modification of constant pressure and constant volume, somewhat like Diesel. There is no doubt that a great deal has to be done yet in the way of constant-pressure engines, the reason being that all such engines, whether of the Brayton type, or of the Diesel type, or of the old type I tried, require gas to be stored up under enormous pressures. If we take, for instance, a cool mixture of gas and air, and apply compression to the full pressure, on ignition we get a pressure of about two tons on the square inch, a pressure which would require extremely heavy reservoirs. This is, perhaps, the chief difficulty of the Diesel type. If the charge in a Diesel engine happens to get in at high temperature, and the cylinder misses ignition by any chance, as I believe in the early experiments it did—at least, I should have expected it to do so, and I believe it did—then an explosion would occur. Supposing the mixture is compressed to 500 lbs. on the square inch only, an explosion occurs, and a comparatively small rise of temperature soon runs up the maximum pressure to one ton on the square inch. The consequence is that you really do get explosion and not combustion. That is the main reason why the constant-pressure type has never come in for gas engines. Nobody has been able to control the effect.

Most large engine designers are now going in the direction of double cylinder double-acting engines, both in this country and on the Continent. The reason for this is obvious. By using two double-acting cylinders tandem, the power is doubled with small weight addition-- little more than the addition of the extra cylinder—so that the crank is fully utilised and the weight for a given power materially reduced.

Fig. 25 is a cross section of the valve arrangement of the Deutz engine showing the governor gearing. In the ordinary large gas engine the hit-and-miss system has often been used, but in the more modern engines, the governing is more like that which is usual in a petrol engine, that is, the charge is throttled. In the case illustrated the charge is throttled by the governor (*b*), operating the bell crank lever (*a*). When the rod (*c*) is lifted by means of the cam (*d*), it leaves the governor quite free to define the fulcrum of the lever (*e*). When the governor operates, the lever (*a*) is correspondingly moved, changing the position of the fulcrum of the lever (*e*). The consequence is, that though the cam lifts the rod at the same time, and opens the valve at the same time, the lift of the valve is varied, and in that way a very good governing is obtained.

Locomotive and Railway Notes.

By CHAS. S. LAKE.

Steam Motor Car, Great North of Scotland Railway.

THE Great North of Scotland Railway is the latest of the railway companies in Great Britain to adopt the rail steam motor for working suburban traffic, and by the courtesy of Messrs. Andrew Barclay, Sons, & Co., Ltd., Kilmarnock, the builders of the locomotive, we are able to give some leading particulars, which may be readily followed by reference to the accompanying illustrations. Two cars have been built, the locomotive superintendent to the railway company, Mr. William Pickersgill, being responsible for the general design.

The interior of the car consists of one compartment with the entrance at the rear end, provision being made for forty-six passengers, all one class. Lattice seats with reversible backs are fitted throughout the length, with a central passage.

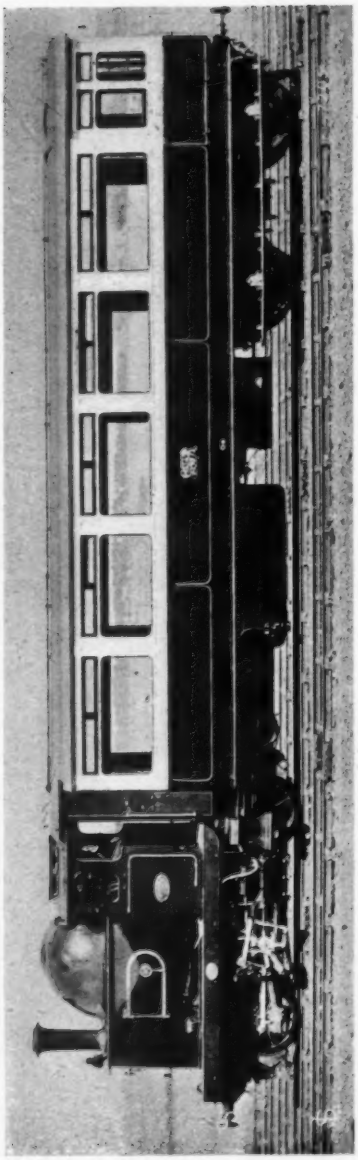
The special feature of the car consists in the type of locomotive used. The boiler specified was either Cochran or horizontal multi-tubular, and Messrs. Barclay determined on using the Cochran type, so as to obtain the necessary shortness of locomotive and good steaming power. The shell is 6 ft. diameter and 9 ft. 6 in. high overall, and has a grate area of 9 sq. ft., with a heating surface of 500 sq. ft. There are 295 horizontal return fire-tubes, each 3 ft. 11¼ in. long by 1¾ in. outside diameter. The working pressure is 150 lbs. per sq. in. Firing is done from the foot-plate in the usual manner, but the products of combustion leave at the side of the fire-box, to pass, after being diverted by a fire-brick arch, through tubes set in a direction transverse to that usual in locomotive practice. The gases then enter a combustion chamber from which they pass through another set of tubes to a chamber above the fire-brick arch, reaching the chimney by a flue. The furnace, which is almost hemispherical in shape, is pressed from one piece and has therefore neither seams nor rivets exposed to the action of the fire.

The engine cylinders are 10 in. diameter by 16 in. stroke, and are fitted with Walschaert gear, the valves working on sloping faces above the cylinders. The gear has very special case-hardening throughout to give special wear.

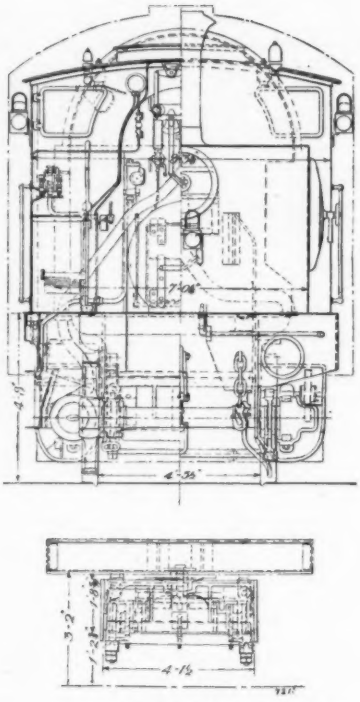
Rocking shafts and levers are carried from the vestibule at the rear end of the car to the cab, communicating motion to the throttle valve, and this enables the car to be worked from either end.

The car frame passes under the footplate, and carries a pivot piece which sits in a movable bolster working between sliding faces and resting on springs, the whole being carried on two knife edges. This arrangement has the effect of minimising the vibration of the engine, and permits of

COCHRAN TYPE BOILER: STEAM MOTOR CAR, GREAT NORTH OF SCOTLAND RAILWAY.



STEAM MOTOR CAR, GREAT NORTH OF SCOTLAND RAILWAY.



ENGINE DETAILS: GREAT NORTH OF SCOTLAND STEAM MOTOR CAR.

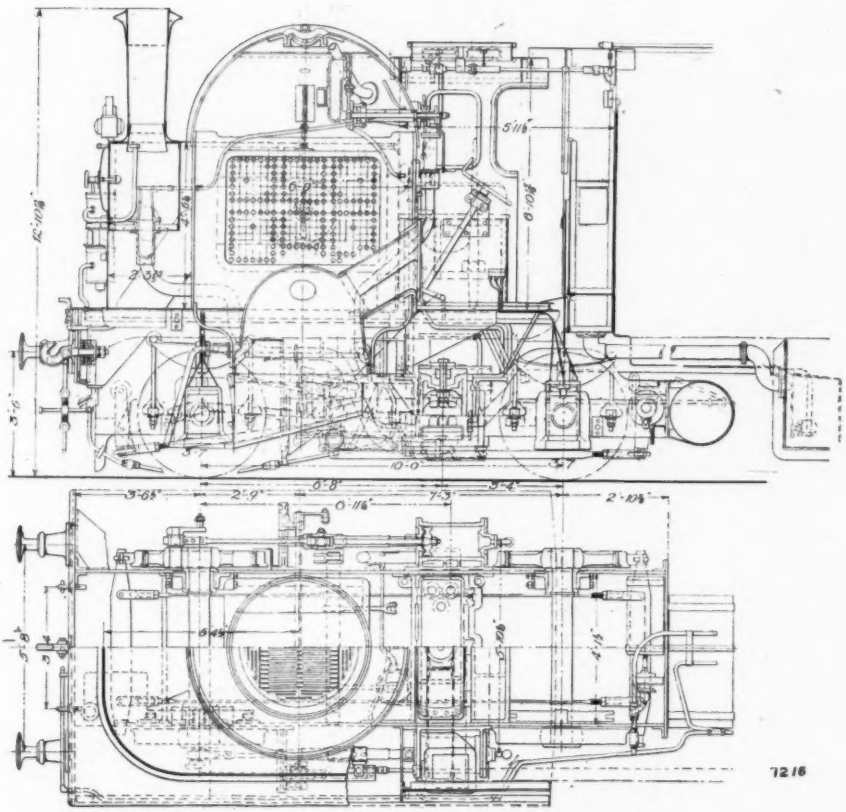
the carriage being detached therefrom. The locomotives have been turned out in excellent style and finish by Messrs. Barclay, Sons, & Co. under the tests of and wholly to the approval of Mr. Pickersgill.

The car is lighted throughout with electricity, the lamps being arranged in clusters at intervals. The dynamo is driven from a carriage axle.

The interior is plain wood varnished except the roof, which is lined with lincrusta white in colour.

The first motor car was run in a number of trials near Inverurie with highly satisfactory results, attaining high speeds in the experiments, keeping steam well, and with a rapid acceleration from starting. Both cars are now in regular service near Fraserburgh.

The car bodies were built at the Great North of Scotland Railway Company's Work's, Inverurie, and connected to Messrs. Barclay's engines at those works.



ENGINE DETAILS: GREAT NORTH OF SCOTLAND STEAM MOTOR CAR.

The Great Northern Railway Compound Locomotive, No. 292.

THE four-cylinder compound 4-4-2 type, express locomotive, No. 292, designed by Mr. H. A. Ivatt, M.Inst.C.E., chief locomotive engineer of the Great Northern Railway, and built at Doncaster Works in the early part of the present year, was the subject of an illustrated description which appeared on page 173 of THE ENGINEERING REVIEW for August last. The engine, it will be remembered, has high-pressure cylinders 13 in. by 20 in. placed outside the frames, driving the second pair of coupled wheels, and low-pressure cylinders 16 in. by 26 in. between the frames, operating the crank axle of the leading pair. Separate valve gears are used for each cylinder. Open backed, balanced slide valves, actuated by Walschaerts' motion, are employed for distributing steam to the outside cylinders, and "Stephenson" gear, with balanced slide-valves of the "Richardson" type for the inside cylinders. The engine is provided with a change valve, by operating which it can be worked either as a simple, or a compound, to suit the circumstances met with in the course of a run, a margin of power being thus available for assisting at the initial effort of starting, and for overcoming increased train resistance on gradients, &c. The coupled wheels are 6 ft. 8 in. diameter on tread, spaced 6 ft. 10 in. between centres, and of the total weight of engine, viz.: 69 tons; 36½ tons are loaded upon the driving axles, this proportion being therefore available for adhesion purposes. The

boiler has a total heating surface of 2,500 sq. ft. and carries a working steam pressure of 200 lbs. per sq. in.

The writer, having received a number of enquiries relating to the character of the work performed by No. 292, recently made a series of journeys on trains hauled by that engine, facilities for the purpose being kindly granted by the Great Northern Railway authorities.

The work noted was throughout of a uniformly meritorious character, the engine hauling, with apparant ease, the trains given it to deal with. It will not be necessary for present purposes to refer to more than one of these journeys, the details of which may be accepted as typical of the rest. On the occasion referred to, No. 292 was attached to the special Edinburgh express, leaving King's Cross at 11.25 a.m. This train runs during the summer months only, travelling via Harrogate instead of York; the first stop being made at Doncaster. It was, on the day in question, comprised of seven bogie corridor coaches and one six-wheeled brake van, and with the exception of the latter vehicle, the whole of the stock was of the latest "East-Coast" pattern, vestibuled throughout, including two dining cars, one first and one third class. Three of the vehicles had six-wheeled bogies, the remainder being mounted upon two four-wheeled bogies. This load is reckoned as thirty-seven pairs of wheels, and the official weight is given at 233 to 234 tons behind the tender, without passengers and luggage.

A punctual start was made, the engine getting under weigh with remarkable rapidity, and here it may be said that the rate of acceleration far exceeded that noted by the writer with two-cylinder, simple, engines under similar conditions. This would be partly accounted for by the fact that as far as Finsbury Park Station, No. 292 was being worked simple so that she would be exerting a tractive power equal to that of an engine using boiler steam in two cylinders each about 19⅝ in. by 26 in. with the additional advantage of distributing the work over four cranks instead of two.

Shortly before reaching Finsbury Park Station, the change valve was brought into operation, the difference in the sound caused by the exhaust when the engine began to work compound being at once noticeable from the train. The run of 13 miles to Potter's Bar, all of which is adverse gradient averaging 1 in 200, was covered by the engine in 18 minutes, and it may be remarked in passing that the amount of sparking (as revealed in the tunnels) was infinitesimal. Hatfield, 17¾ miles out from King's Cross was passed at 11.48 a.m., or 23 minutes from starting, and the first 54 miles were covered in the level hour. Peterborough, which is 76¼ miles from London, was passed, at greatly reduced speed, at 12.49 p.m., the run to this point having occupied 1 hour 24 minutes:—an average speed of 54·2 miles per hour. The 15-mile bank, ranging from 1 in 264 to 1 in 178, and culminating at Stoke summit, was negotiated in excellent style, and on passing Grantham, 105¼ miles out, exactly two hours had been expended in running from London. Some exceptionally fine running on the down grade next ensued, the two miles before reaching Claypole being covered at the rate of 70·5 miles per hour, and a high average velocity maintained through Newark and beyond. The first signal check occurred at Grove Road Level Crossing, shortly before reaching Retford, but the latter station was passed at 2.2 p.m., leaving 22 minutes for the 18 miles run to Doncaster. This distance was, however, accomplished in three minutes less time, the train coming to a stop (for the first time after leaving King's Cross), in Doncaster Station, at 2.21 p.m. or three minutes before time;—the 156¼ miles having thus been covered in 176 minutes, an average speed of just over 53 miles per hour. There is nothing, of course, of the "exhibition" character about work of this kind, but it is, nevertheless, sufficient to stamp the engine performing it—economically and with ease—as successful. The writer has no hesitation in expressing the opinion that in No. 292, Mr. Ivatt has designed, and Doncaster Works produced, a very excellent type of engine, and one which may be relied upon to give satisfaction under all reasonable conditions. In limiting the cylinder capacity, and augmenting as far as possible, the boiler power of his engines, Mr. Ivatt is beyond doubt following a wise policy. Locomotives of greater power there may be, but what is the use of providing enormously increased cylinder proportions when the adhesion weight at command is limited to about 18 tons per axle as a maximum?

By raising the boiler pressure and adopting a later cut-off in the first cylinders, and then expanding down to a reasonably low terminal pressure in the second cylinders, the tractive effort necessary for the observance of a correct ratio to the adhesion is forthcoming, and an exceedingly economical and withal powerful engine should, and does no doubt, result.

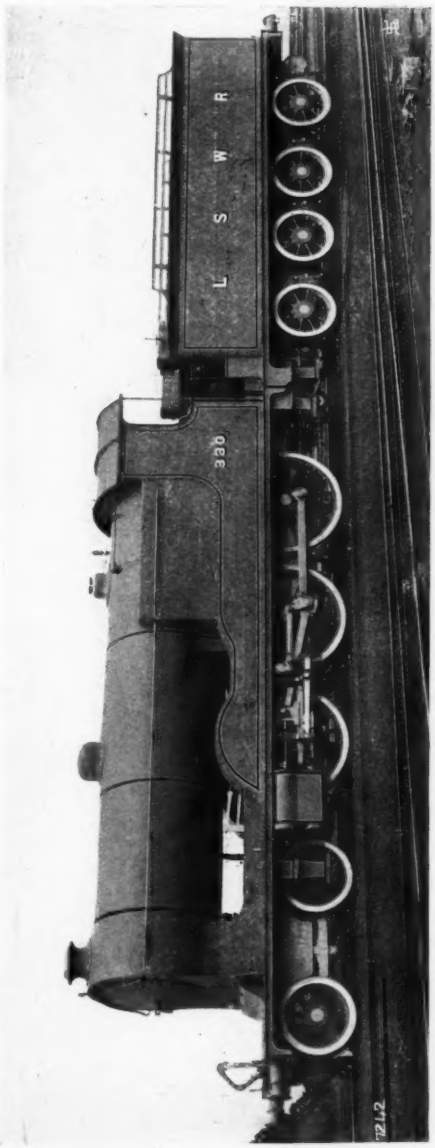
Thanks are due to Mr. Oliver Bury,

general manager of the Great Northern Railway, for facilities granted in connection with the trips referred to above, and also to Mr. Ivatt, who kindly arranged for the engine, No. 292, to be taken off its regular turn, in order that it might work trains selected by the writer.

Latest Type of Passenger Locomotive, L. & S.-W. R.

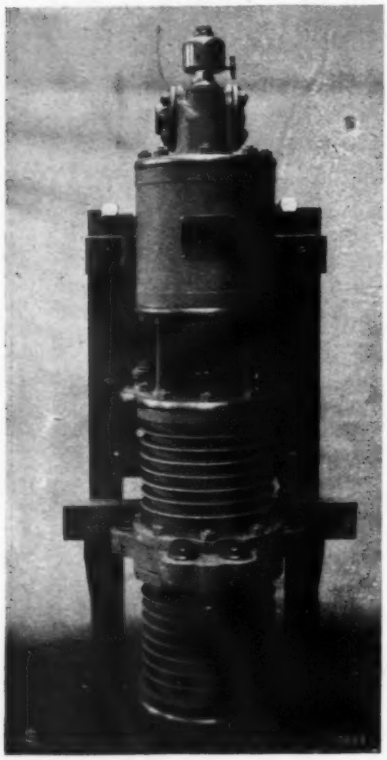
THE writer has already referred on two occasions in these notes to the new four-cylinder, simple, passenger locomotives designed by Mr. D. Drummond, M.Inst.C.E., chief mechanical engineer of the London and South-Western Railway, and now, by Mr. Drummond's courtesy, is enabled to illustrate the first of the type to be completed, viz., No. 330, which, after a series of trial trips, has been put into regular service on the heaviest and fastest passenger trains on the London and South-Western main line.

The cylinders are arranged in pairs for driving separate axles; the inside pair operating the crank axle of the foremost coupled wheels, and the outside cylinders the middle pair. Steam is distributed to the outside cylinders by flat valves actuated by Walschaerts' motion, the steam chests being placed below the cylinders. "Stephenson" valve gear is employed for the inside cylinders, the valves in this case working at the sides of the cylinders. An extremely large boiler is provided, having 2,727 sq. feet of heating surface, the highest total employed on any railway in this country, and the firebox is of the water-tube pattern, with a grate area of 31·5 sq. ft., whilst Drummond's spark-arrester and fuel economiser is located in the smoke-box. The boiler is thus admirably adapted for rapidly generating steam and maintaining a large volume of the same. This is absolutely essential to the successful operation of such engines which, having an enormous cylinder capacity, and at the same time only a limited range of expansion, are great steam users, this being compensated for by the abnormal power they can exert when required to do so. The cylinders are 16 in. diameter by 24 in. stroke,



LATEST TYPE 4-CYLINDER EXPRESS LOCOMOTIVE, LONDON AND SOUTH-WESTERN RAILWAY.

coupled wheels 6 ft. dameter, weight loaded (without tender), 73 tons, distributed as follows:—On bogie, 21 tons, 10 cwts.; leading drivers, 17½ tons; middle, 17½ tons; trailing 16½ tons.



WESTINGHOUSE COMPOUND AIR PUMP.

Westinghouse Compound Air-pumps.

THE writer has been favoured by Messrs. the Westinghouse Brake Company, Limited, with drawings of a compound air-pump manufactured by them.

In this pump there are three cylinders placed vertically tandemwise, the uppermost one being a steam cylinder of the standard "Westinghouse" type, whilst the two lower ones, which are connected together by a centre-piece, are compound air cylinders. The pistons in the latter are joined together by a trunk or drum, formed in one with the upper piston, and the centre piece, already referred to as existing between the two air cylinders, is fitted with packing rings to prevent leakage of air from one cylinder to the other past the drum, this arrangement being clearly shown upon the drawing. On the downward stroke of the piston B, the upper space A is filled with air drawn through the upper air inlet valve F, and the air contained in the lower space A is forced into the annular space E, through the valves K-1 and K-2. When the piston B ascends, this air enclosed in the annular space *e*, is still further compressed, and delivered through the discharge valve M. At the same time during the upward stroke the same action takes place between the upper space A, and the annular space *d*, through the valves G, L-1 and L-2, and as the piston B again descends, this air in the annular space *d* is compressed and delivered through the discharge valve M, thus completing the cycle. The volume of the air in the annular space is much smaller than that of the low-pressure cylinder, and the air is finally compressed in this annular space before being forced out through the passages and valves in the centre piece to the discharge opening and thence to the main reservoir. By compounding the air cylinders of the pump, the capacity is raised considerably when pumping against a high air pressure, owing to the fact that the low-pressure clearance volumes at the end of a compression stroke are filled with air at a low pressure instead of air at a high pressure, as in a simple pump. The volume of air drawn in at each stroke is much greater because of the fact that the pressure of the air in the low-pressure clearance volumes being less, is reduced to atmospheric pressure much earlier during the intake stroke than is possible with the simple pump. From tests made with the compound type, it was found that only about 45 per cent. of the steam required per cubic foot of free air compressed when using the simple pump, is necessary for the same work in the compound pump.

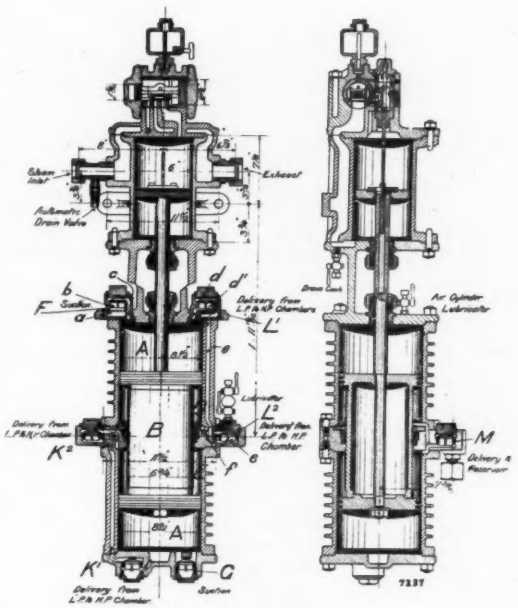
Storage Battery Locomotives for the Great Northern, Piccadilly and Brompton Railway.

MESSRS. HURST, NELSON & Co., Limited, of Motherwell, N.B., have recently built and supplied to the London Underground Electric Railways Co., Limited, two storage battery locomotives for service on the Great Northern, Brompton and Piccadilly

Railway. One of these locomotives is illustrated herewith in sectional elevation.

The main floor is built up of steel girders and plates, and upon this is a casing extending practically from end to end of the vehicle. A driver's cab is provided at each end, both being fitted with a "British Thomson-Houston" controller, whilst accommodation is found in one of the cabs for the electrical and brake apparatus. There are no collector shoes, the power being wholly derived from the battery, the main compartment carrying about thirty-six tons' weight of accumulators. The equipment per car consists of eighty cells with twenty-one plates to each cell, the normal discharge of current being 179 amperes with a maximum emergency load of 800 amperes. The locomotives weigh sixty-four tons each, and have a free running speed, when hauling train-loads of sixty tons, of seven and nine and-a-half miles per hour.

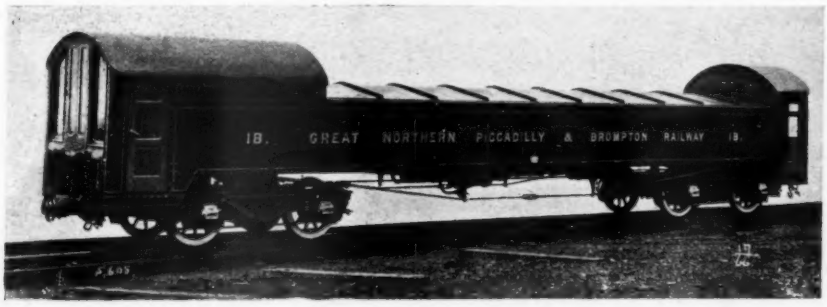
The batteries were supplied by the Chloride Electrical Storage Co., and they are capable of storing sufficient energy for a whole day's operation without recharging. The equipment includes automatic centre-coupler buffers, and both hand brakes and "Westinghouse" air brake appliances. The length of the locomotives over buffers is 50 ft. 6 in., and the width 8 ft.



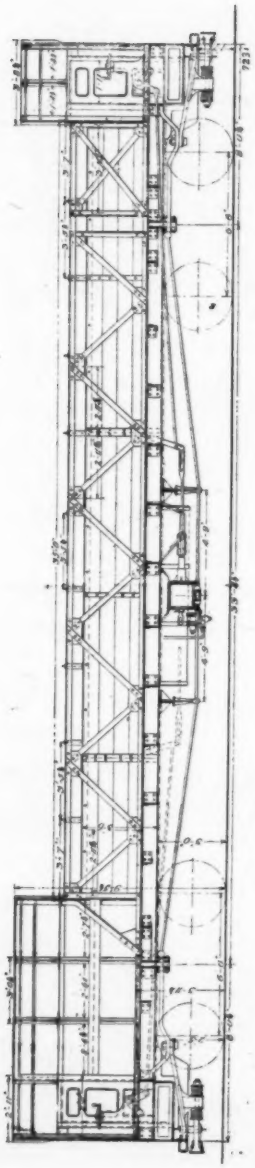
DETAILS OF WESTINGHOUSE COMPOUND AIR PUMP.

Heavy Continental Goods Locomotives.

Locomotives intended for goods train service have been developed upon the Continent to a stage, in respect of weight and power, not yet equalled in this country; indeed, the loading gauge here prohibits the use of engines having proportions similar to those of the largest class employed abroad. Compound cylinders are almost invariably employed in Continental practice for goods locomotives as well as in cases where passenger traffic is concerned, and the most popular type of engine is that known as the "Consolidation" or 2-8-0 type, which



STORAGE BATTERY LOCOMOTIVE, GREAT NORTHERN, PICCADILLY AND BROMPTON RAILWAY.

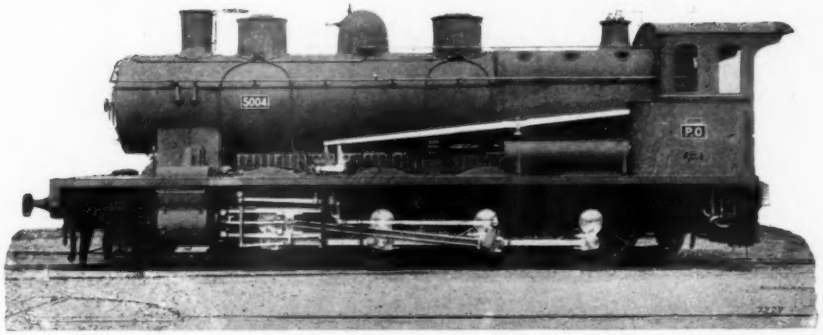


STORAGE BATTERY LOCOMOTIVE GREAT NORTHERN, PICCADILLY AND BROMPTON RAILWAY.

presents an opportunity for employing a large proportion of the total weight of the engine for adhesion purposes, whilst at the same time including a flexibly arranged front end. Examples of locomotives of this type from the most modern Continental practice are illustrated herewith. Fig. 1 shows one of a recent series built by the Société Alsacienne de Constructions Mécaniques, of Belfort, for the Paris-Orleans Railway. These engines have four compound cylinders, the two high-pressure being placed between the frames in an inclined position below the smoke-box to drive the crank axle of the second pair of coupled wheels, whilst the low-pressure cylinders are located outside the frames and drive the third pair of coupled wheels. The steam chests are, in all cases, above the cylinders, and the valve-gear is Walschaerts' for the low-pressure, and "Stephenson" link-motion for the high-pressure cylinders, the reversing gear being so arranged that the driver can vary the admission of steam to the two pairs of cylinders, either simultaneously or in two successive operations. The engine is fitted with a Belpaire boiler of large size, upon which are mounted a steam dome and two capacious sand-boxes, of cylindrical form, with pipes delivering sand on both sides of the h.-p. driving wheels, and also to the leading and intermediate coupled wheels. A commodious cab, with side windows and extended roof, is provided, and both Westinghouse and steam brake appliances are fitted. The tender runs upon four wheels, and is of small capacity. The following are the principal dimensions:—

Cylinders (h.-p.) ...	15 1/2 in. dia.
,, (l.-p.) ...	23 3/4 in. dia.
Piston stroke ...	25 5/8 in.
Coupled wheels	5 ft. 1 in. dia.
Bogie ,, ...	2 ft. 9 7/8 in. dia.
Boiler, mean dia. of barrel	5 ft. 5 3/8 in. dia.
,, length between tube plates,	14 ft. 5 1/2 in.
Working pressure ...	228 lbs. per sq. in.
Total heating surface (internal measurement)	2'577 sq. ft.
Height of boiler axis above rail	8 ft. 10 1/4 in.
Grate area	33'4 sq. ft.
Weight on coupled wheels	66 tons.
Weight on bogie ,, ...	7'4 tons.
Total weight of engine loaded (without tender)	73'4 tons.

Fig. 2 shows one of the large 2-8-0 type "Mellin" compound goods locomotives built by Messrs. Nydqvist and Holm, of Tröllhattan, Sweden, for working heavy mineral trains on the Luleá Riksgränsen section of the Swedish State railways. A truck of the "Krauss-Helmholz" type is used for carrying the front end of the engine, and the cylinders, two in number, are arranged outside the frames with the low-



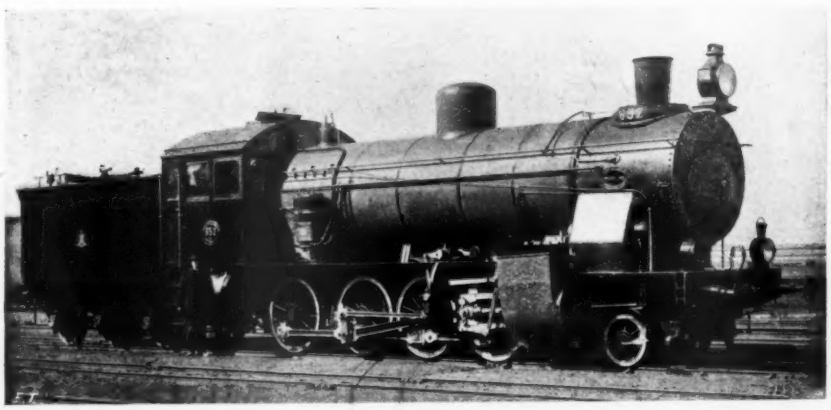
HEAVY CONTINENTAL GOODS LOCOMOTIVE (FIG. 1).

pressure to the right and the high-pressure to the left of the engine. The valve gear is of the "Heusinger-von-Waldegg" type actuating valves on top of the cylinders, and screw reversing gear is used. The reducing and intercepting valves are located in a box on the right-hand side of the smokebox. The cab is of wood, with steel plating. It is specially designed to protect the men from the rigours of the climate. The engine has 21½ in. by 25½ in. h.-p. cylinder, and 32 in. by 25½ in. low-pressure, and coupled wheels 4 ft. 3$\frac{3}{16}$ in. dia. The boiler is 5 ft. 8$\frac{7}{8}$ in. dia. inside; steam pressure, 205 lbs. per sq. in.; total heating surface, 2,280 sq. ft.; grate area, 31 sq. ft.; weight of engine and tender, 106 tons.

Automatic Surface Grinding Machine.

MESSRS. LUKE AND SPENCER, LTD., of Broadheath, Manchester, have introduced an automatic grinding machine which is specially intended for preparing flat surfaces such as locomotive slide bars, keys, cotters, and other detailed parts. A stiff cast-iron frame carries the grinding-wheel, and the spindle for this wheel runs in adjustable brass bearings arranged for steady running and to prevent springing of the spindle.

The wheel, in addition to its rotating movement, has reciprocating motion, this being imparted by means of a worm and

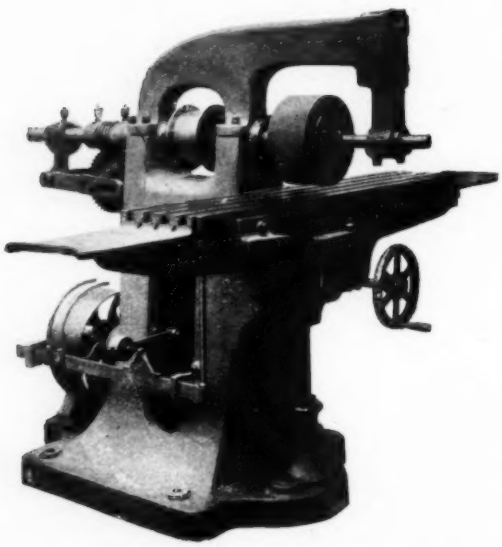


HEAVY CONTINENTAL GOODS LOCOMOTIVE (FIG. 2).

wormwheel from the spindle at the back of the machine.

The work is carried upon a sliding table in front of the standard. This table has an automatic traverse, being fed by reversing pulleys and gearing also at the back of the machine. Stops on the front of the table adjust the length of the traverse, and a hand-wheel operating through worm and wormwheel on to the screw makes it possible to raise or lower the table at will, the arrangement being such that a very fine feed or vertical adjustment can be secured. Two countershafts are provided, one for driving the emery wheel and the other for the reversing pulleys.

Accuracy in grinding surfaces is ensured by means of the lateral movement of the emery wheel across the work, combined with the longitudinal traverse of the latter under the wheel. The machine is capable of producing the best results, whether in cast-iron or hard or soft steel, and is an excellent substitute for the filing and scraping operations frequently employed in many shops.



AUTOMATIC SURFACE GRINDING MACHINE FOR LOCOMOTIVE PARTS

Electrical Notes.

By ANDREW STEWART, A.M.I.E.E.

Considerations Governing the Choice of an Electric Power Plant.

THE paper read to the New England Railway Club, by Mr. T. W. Adams, of the New York, New Haven, and Hartford Railway Company, on the above subject is of interest to works owners generally, as indicating one view of the considerations involved in the choice of a factory equipment. The supply to the railway shops was in the form of alternating current from a local power company, and the desirability of using the alternating current or changing it to direct current, received a good deal of consideration at the hands of the company. Eventually it was decided to retain alternating current, except for the transfer table, where, owing to the necessity for wide speed control, a direct current motor was fitted. The determining factors in the choice of induction motors for the remainder of the works, were that alternating current motors were able to handle very heavy overloads without the slightest injury, hence smaller motors than would have been desirable with direct current, were installed with a corresponding saving in capital. The absence of commutators and brushes reduced the maintenance costs, and owing to the use of the motors in hazardous risks such as the paint shop and wood-working departments, the absence of almost the only source of fire risk in a direct current motor was a further argument in favour of alternating current machines. The question then became one of how far should the sub-division of the motive power be carried, this was approached from two extreme points, viz., the driving of every machine by its own motor, entirely excluding belts and shafting, and the retention of most of the shafting, and the use of one or two large motors. The first of these was considered extravagant because of the large amount of capital involved, and the low efficiency of the small motors: The second, while economical in capital, was extravagant in operating expenses, indeed the additional cost in this direction would, if saved by the substitution of the individual motor drive, have paid a reasonable interest on the capital cost of the first scheme. The two methods were brought nearer to each other by a process of elimination, and subsequently a compromise of driving such isolated machines as were used intermittently by individual motors, and driving such machines as could be conveniently driven from short shafts, which were driven by motors smaller than the aggregate power of the machines forming the group, as the average load was usually much less than the maximum.

It does not appear from the paper that due consideration was given to the collateral advantages of electric driving, the subject having been approached from the point of view, of capital and operating expenses. Power costs are a relatively small part of the total cost of the finished product of any factory, and the dominant influence of labour should be considered; any increase in the output due to greater flexibility or ease of control of the machine, would by decreasing the labour cost per unit of output, and by lowering the fixed charges due to the shortening of the machine time on the work, easily upset the conclusions reached by the author of the paper, and justify a much more extensive use of motor driven tools.

A Combined Petrol and Electric Automobile.*

THE figure shows an automobile designed to give the flexibility and ease of control inherent to electric driving at slow speeds, with the efficiency of a direct drive from the petrol engine at full speed. Two electric motors are geared to the rear axle for driving the vehicle at slow speeds, current being supplied from

* *Electrical World and Engineer*, September 4th.

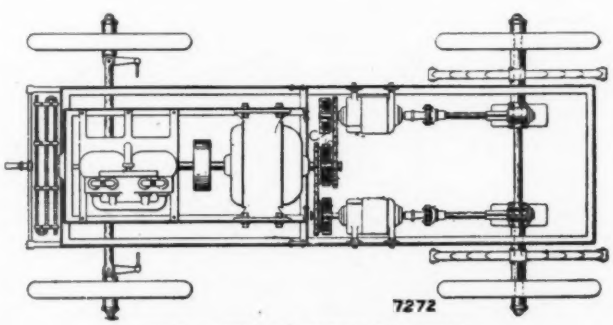


FIG. 1.—PETROL AND ELECTRIC AUTOMOBILE.

the dynamo shown in the middle of the vehicle. At full speed, in order to eliminate the losses due to the double conversion of energy, the sprocket wheels shown at the rear of the engine and dynamo shaft, are thrown into gear by means of a magnetic clutch, the dynamo and motors then run free, and the petrol engine drives the rear axle direct. This is an interesting adaptation of the electric driving on the electrically-driven oil tank steamer *Vandal*,* where experience with that steamer has shown that precisely similar driving arrangements were desirable on such vessels. The control of the motors on the automobile is series-parallel, as in an electric tramcar, and no differential gear is necessary, because at slow speeds the motors provide the proper differential action, and at high speeds when engine and motor shafts are direct connected, the elimination of any differential gear seems to diminish the liability to skidding.

The Electric Power Equipment of the B.F. Sturtevant Company's Works, Boston. U.S.A.†

THE site consists of twenty acres of land of which about nine acres are covered by twelve buildings. Their arrangement is such that all transportation of material or of machinery in course of construction is in a straight line. An inter-shop railway, having a gauge of 2 ft., is laid throughout the entire works, while, in addition, overhead cranes, pneumatic, electric, and hand hoists, and electric elevators are fitted wherever circumstances demand such appliances. The building is composite, having steel columns and main steel girders, with brick walls, timber floors, and plank roofs. Ribbed glass is used in all except the lower window panes, the machine shop has saw tooth skylights, the glass facing due north. Artificial lighting is obtained chiefly from enclosed arc lamps, though bench lighting is obtained by means of 16 c.-p. glow lamps, and the latter are so arranged that the workman has a left shoulder light. Fire protection is secured by 3,800 "Grinnell" automatic sprinklers, and convenient fire hose, while self-closing fire-proof doors are fitted between various departments. The power house contains 1,000 h.-p. of "Stirling" boilers fitted with "Sturtevant" mechanical draught apparatus, and an economiser. There are two generating sets, one of 100 kilowatts, and one of 250 kilowatts, the engines are vertical cross compound condensing. A tunnel 6 ft. 6 in. high by 5 ft. wide, connects the generating station with the main factory buildings; this contains the steam heating, compressed air pipes, and electric cables. For steam heat a pressure of 5 lbs. per sq. in. is employed. All wiring is two wire 220 volts, and there are about 100 electric motors from ¼ h.-p. to 40 h.-p Group and individual drive are both used; in the former case machines are so arranged that each group requires about 20 h.-p., and motors of this size are employed. Motors above 10 h.-p. have circuit breakers, below this size fuses are employed. Starters are in all cases fixed so that the workman can control the machine without interfering with his normal duties. These starters are fixed in iron boxes with self-closing doors lined with asbestos. The more important tools having individual drive are as follows:

Machine.	How Driven.	Size of Motor.
60 in. open side 16 ft. planer	belt	15 h.-p.
72 in. „ „ 18 ft. „	„	20 h.-p.
Back-geared vertical boring mill, 6 ft. swing	„	1½ h.-p.
Vertical boring mill, 8 ft. swing	„	10 h.-p.
Horizontal „ „ 5 ft. „	geared	2 h.-p.
Lathe, 24 in. centres	„	7½ h.-p. (variable speeds.)
60 in. × 48 in. 16 ft. Cincinnati planer, with four tools	„	20 h.-p.
"Landris" grinder, with mechanical control from working centre	belt	15 h.-p.
76 in. boring mill	„	5 h.-p.
Chucking lathe	geared	3 h.-p.
Niles' 60 in. boring mill, 2 heads	belt	12 h.-p.
"Niagara" circular shear	geared	10 h.-p.
"Bliss" gate shear	„	15 h.-p.
Bending rolls	„	15 h.-p.

The machine shop is served by a 10-ton crane, 37-foot span, 23-foot lift, hoisting speed 15 ft. per minute, with 15 h.-p. motor. Longitudinal travel 120 ft. per minute, 15 h.-p. motor. Cross traverse 350 ft. per minute, 2½ h.-p. motor. The test room has a 15-ton crane with the same size motors as the machine shop crane. There are two cupolas: one 56 ins., and one 72 ins. diameter. The smaller one is supplied with air from a No. 8 "Sturtevant" pressure blower driven by a 30 h.-p. motor, the latter by a No. 10 blower, driven by a 40 h.-p. motor. About 1,000 tons of plates are stacked on edge in the fan shop, and by means of a specially designed two-wheeled trolley one man can easily handle sheet iron plates 10 ft. by 5 ft. 4 ins., by ¼ in. thick, weighing 320 lbs., these had formerly to be handled by several labourers.

Electric Traction on Railways by Single-Phase Currents.

DURING the last month there has been an unusually large number of articles in the American and European papers on the above subjects. Most of them deal with the electrical details, but among the mass of electrical matter is a good deal of information of value to the engineer who is following developments in this direction; such results as have been published*

* ENGINEERING REVIEW, June, 1905.
† *Electrical World and Engineer*, New York, September 30th.

* ENGINEERING REVIEW, Vol. xii., pages 735, 874, and 875; Vol. xiii., page 179.

go far to prove that for main line traction no more promising system has yet been evolved. Among the earlier lines, the Schenectady-Ballston line, equipped by the General Electric Company (U.S.A.) has been in operation about a year and the new rolling stock differs from the earlier plant only in respect of speed of the motors, which has been reduced from 1,500 revolutions in the earlier machines, to 1,350 in the new plant; this change was found desirable on account of the short life of the brushes at the higher speed. The control is plain series, all four motors being connected permanently in series instead of series parallel as at first, and the speed control is obtained by varying the voltage at the motor terminals by taps from five points in an oil insulated auto-transformer. Some of the earlier auto-transformers were cooled by a blast of air, but it was found that dust and moisture were sucked in, and clogged the ventilating ducts. An interesting feature of the new equipment is the use of a main switch, which can only be closed when the circuit from the trolley wire to the rails is complete. The reason for this is that if there should be sand or ice on the rails and the current is "on" no current can pass from the locomotive frame, which is "earthed," to the rails which form the return circuit, consequently the whole frame is at the potential of the overhead line, and as this is often several thousand volts, a plate-layer, or even the engine driver or motor man, if standing on the track and touching any part of the truck or wheels, would get a shock equal to the full pressure. The use of this switch entirely eliminates this risk by cutting off the current immediately the connection between the car and the rails becomes defective. Owing to the fact that the single-phase motor has a torque which pulsates with twice the periodicity of the supply current, the maximum torque at the periphery of the driving wheels can never exceed that due to the maximum adhesion between driving wheels and the rails; indeed this variable torque is not unlike that due to the cranks of a steam locomotive. As, however, the torque effective in producing acceleration is the *average* torque, it would seem that the single-phase motor is incapable of giving the acceleration which direct or polyphase motors give. This is really the case, but by suitable spring suspension it is possible to largely eliminate this disadvantage so that only the mean torque does reach the driving wheels.

In cases where the cars run over lines where direct-current supply only is available, no change is made in the grouping of the motors, but rheostatic control is substituted for the auto-transformer method of pressure regulation. Another single-phase line which has now been in operation for about a year is the Indianapolis-Rushville line, which has a "Westinghouse" equipment operating 48-ton cars at speeds up to nearly 70 miles per hour. The line is 40 miles long and the trolley pressure is 3,300 volts. Full particulars of this equipment were given in these notes in our April issue, and the results of subsequent experience proves that except for trouble due to inadequate insulation on some of the motors, which has now been remedied, no difficulties have been experienced. The sliding bow trolley is employed instead of an ordinary

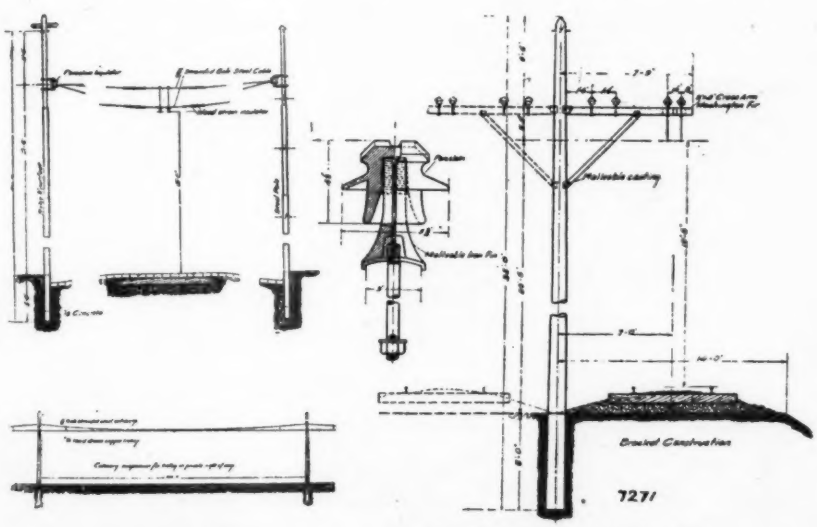


FIG. 2.—LINE CONSTRUCTION, BLOOMINGTON, PONTIAC, AND JOLIET ELECTRIC RAILWAY.

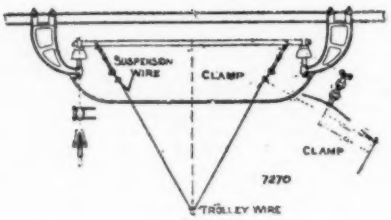


FIG. 3.—DETAILS OF CATENARY SUSPENSION.

wheel, as this is less likely to leave the overhead wire at high speeds.

A line which has proved the remarkable reliability of the system is the Pontiac-Odell railway opened in March this year. From the opening till early in August there was only one car, and it made eight round trips per day between the two towns without any interruption; for the first two months there was no car shed, so that any repairs or examination had to be made between the last run at night and the first morning trip, moreover these had to be effected in the open air for two months. As each round trip is 20·8 miles it is apparent that the performance of a car which ran 23,000 miles before it was possible to take it off the road for repairs of any kind, and moreover was equipped with a system regarding which no previous experience had been gained, indicates a fair amount of robustness. It has been found as indicated earlier, that when starting up from rest the car does not accelerate so rapidly as similar cars with direct current motors, but after the first two or three seconds, the acceleration is pretty much the same. This line uses the ordinary wheel trolley. Some details of the line construction are given (Fig. 2), from which it will be seen that the poles are usually between the up and down tracks, but at certain points, where the line is single, a span wire suspension is employed. Catenary suspension is now used on most single-phase lines, the details of the steel supporting cables can be seen from the upper left hand figure. The average speed maintained, including time lost at turn-outs on the single track, is 20·8 miles per hour. In Germany the towns of Neiderschoneweide and Spindlersfeld are connected together by a short line, over which trains consisting of two motor cars and three trailers weighing about 170 tons and propelled by motors of 480 h.-p., (two motors each of 120 h.-p. per motor car), maintain a schedule speed of 22 miles per hour. The trolley wire pressure is 6,000 volts and the periodicity of the supply is 25 cycles. The trolley wire is supported by two steel suspension wires as shown (Fig. 3). The insulators used are shown in section on the left hand side, and the difference in type of insulator and method of suspension, due to higher pressures, and desirability of being able to maintain service even if one of the trolley supports should break, compared with the usual trolley construction, will be noted. Bow trolleys are employed instead of the usual wheel trolley. A more important single-phase line has just been completed between Vienna and Baden. The generating station is about 1¼ miles from the latter town, and contains two 200 kilowatt, 10,000 volt, single-phase alternators and two smaller direct-current generators for local service. The motor cars have four 50 h.-p. motors, which can run on direct or alternating current, and weigh 18½ tons. The high pressure already mentioned is transformed down to about 6,000 volts by transformers having a capacity of 110 kilowatts (about 150 h.-p.), situated at intervals along the line, at which pressure the trolley wire is fed. The rolling stock consists of 13 motor cars and 18 trailers. The latter weigh about 10 tons.

By PERCY LONGMUIR,
Carnegie Research Medallist.

The Iron and Steel Institute Autumn Meeting.

The Department of Iron and Steel Metallurgy at the University of Sheffield.—Sheffield, as a steel manufacturing centre, has an established and recognised position. With this recognition the fact must also be coupled that, educationally, Sheffield has established an unrivalled system of training in the metallurgy of iron and steel. This is most forcibly shown in Professor Arnold's paper describing the equipment and appliances possessed by the department of metallurgy at the University of Sheffield. As Professor Arnold very pertinently remarks, the day has passed when metallurgy could be taught by means of an equipment consisting of an assay laboratory, blackboard, and chalk. The equipment used for teaching purposes is, in more senses than one, that of a model steel works, comprising coke and gas melting crucible furnaces, apparatus for the manufacture of crucibles, annealing grate and annealing furnace. The Siemen's open hearth furnace is of the new form, and has a capacity up to 2½ tons. The Bessemer plant consists of a 1 ton vessel fitted so as to take a shallow bottom blown bath, a side blown heat by the Robert modification, or a surface blown heat by the modification of Tropenas. The blowing engines deliver 2,750 cubic feet per minute of uncompressed air, or 2,000 cubic feet per minute at a pressure of 5 lbs. per sq. in. The cupola, a Whiting, is lined up to 39 inches, has a drop bottom, and receives blast from a Roots' blower, which is in turn motor-driven. The hammer is capable of dealing with 4 in. ingots, and strikes one hundred blows per minute. The ingots are heated in a coal-fired re-heating furnace. A "Clinch Jones" heat treatment muffle is connected with a "Uehling" recording pyrometer. A "Pifton" heater is employed for drying moulds, and these are in turn handled by a 4 ton overhead travelling crane.

The mechanical testing equipment comprises a 50 ton "Wicksteed" machine with two centres, capable of registering tensile, compressive, transverse, or torsional stresses in either 3 in. or 12 in. ton moments. An alternating stress apparatus is capable of making 30 or 40 tests per hour, thus bringing the "Wöhler" test into the range of everyday works metallurgy. There is also a 20 ft. ton falling weight apparatus, the mild steel bed block of which weighs 2¼ tons, and was cast in the foundry attached to the department.

The micrographic installation consists of a series of motor-driven polishing blocks and eleven microscopes, including the latest of "Zeiss" photo-micrographic apparatus. There are four chemical assay laboratories providing accommodation for one hundred and two students working at one time. The geological laboratory is equipped with a set of petrological microscopes and rock section, cutting, and polishing apparatus. The pyrometric installation consists of a central station "Le Chatelier" pyrometer, which can be connected by means of a switch board to any of the practical or laboratory furnaces. In connection with this is a furnace for measuring recalescence, in vacuo, together with a keyboard and an electric chronographic recorder. The "Uehling" pyrometer has been mentioned; in addition there are optical pyrometers by Mesurè and Nouel, and Wanner; a portable pyrometer by Paul; and one by Baird and Tatlock.

The Thermal Transformations of Carbon Steels.—This memoir by Professor Arnold and Mr. McWilliam will serve a useful purpose in clearing away much of the complexity which at present envelops the literature of the constitution of steel. The work is confined to carbon steels, and the authors have examined the transformations of (*a*) saturated steel, (*b*) unsaturated steel, and (*c*) super-saturated steel. The conclusions reached are as follows:—

Saturated Steel.—Such a steel on heating presents a single absorption of heat at the change point Ac. 1, 2, 3, and the amplitude of which

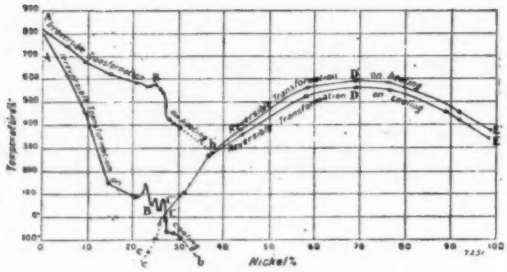


FIG. 1.—POSITIONS OF THE POINTS OF ALLOTROPIC TRANSFORMATIONS OF NICKEL STEELS WITH PERCENTAGES RANGING FROM 0 TO 100.

ranges from about 710° C. to 730° C. This change marks the transformation of the whole mass from pearlite into hardenite. On cooling there is a considerable evolution of heat at the single point Ar. 1, 2, 3, the amplitude of which ranges from about 690° to 660° C. This recalescence marks the transformation of hardenite into pearlite. The character or phase of the pearlite is determined by the rate of cooling from 660° C. Thus the emulsified phase is obtained by very rapid cooling, normal pearlite by ordinary cooling, and laminated pearlite by very slow cooling. Emulsified or sorbitic pearlite may also be produced by tempering hardenite.

Unsaturated Steel.—At temperatures exceeding Ar. 3, *i.e.*, 810° C. ferrite and hardenite are in mutual solution as a homogeneous mass. The Ar. 3 change is accompanied by a segregation of the two constituents, which if the cooling be slow is probably completed in the Beta range of temperature. Results show hardenite to be insoluble in ferrite in both the Beta and Alpha ranges of temperature. At about 680° C. hardenite begins to decompose into pearlite. On heating an unsaturated steel the transformations are as follows: At $Ac._1$, about 710° C. pearlite begins to change into hardenite, and when $Ac._3$, about 810° C. is reached hardenite and ferrite dissolve into each other, forming a homogeneous molecular mixture.

Super-saturated Steel.—At Ac. 1, 2, 3, the sectional ground mass of pearlite changes to hardenite, and cementite slowly segregates into larger masses until a temperature of about 900° C. is reached, then cementite and hardenite dissolve one into the other, and a homogeneous mass of hardenite and cementite is obtained. On cooling cementite falls out at about 900° C., and is completely segregated long before the point Ar. 1, 2, 3 is reached, hence the micrographic transformations of cementite and hardenite are quite unconnected with the critical points, and are due entirely to the influence of temperature.

The Reversible and Irreversible Transformations of Nickel Steels.—In considering the transformations of nickel steels, M. Dumas, in the first place, reviews the earlier work in this field, referring more especially to Hopkinson's experiment of 1899. In this case a 25 per cent. nickel steel, which was non-magnetic at ordinary temperatures, became magnetic on cooling to slightly below 0° C. and highly magnetic at —51° C. On returning to normal temperature it remained magnetic, and only ceased to be so at 580° C. This steel was, therefore, capable of existing between ordinary temperature and 580° C. in two different states, characterised by the appearance or disappearance of magnetism and likewise by different mechanical properties, the magnetic sample possessing a higher tensile strength and a lower elongation on fracture. Following this the work of Guillaume and Osmond is indicated, the latter especially showing the lowering of the transformation points of iron under the influence of additions of nickel, and the increasingly accentuated irreversible transformation in proportion as the nickel rises. Above 25 per cent. nickel the transformation becomes reversible, and these investigations result in the division of nickel steels into two classes, according as their contents of nickel are above or below 25 per cent. Experiments quoted show that it may be necessary to place the limit at which nickel steels no longer undergo the irreversible transformation in the vicinity of 31 per cent. nickel. However, there is nothing to indicate that this content is an absolute limit, but the irreversible cooling transformation point recedes further and further from the reversible transformation point as the content of nickel rises. In studying the action of elements other than nickel, it is shown that carbon plays the same *rôle* as nickel, but has a greater intensity, and one unit of carbon will produce the same amount of lowering as twenty units of nickel. Similarly the lowering of the transformation points by manganese is more rapid than that of nickel, but slower than that of carbon. The addition of chromium to a nickel steel results in a lowering of the irreversible transformation point; it is, however, shown that this lowering is not due to chromium alone, but to the intensifying action of chromium on carbon. In the accompanying diagram M. Dumas has collated his determinations of transformation points in nickel steels of gradually increasing contents of nickel and low amounts of carbon and manganese.

Examination will show that the curves of the two transformations intersect each other at a point determined by the proportion of carbon and manganese present. For steels containing few elements other than iron and nickel this point of intersection is situated above the ordinary temperature, and in the vicinity of 27 per cent. nickel. The rise of the curves follows a content of nickel and temperature

which are lower in proportion as the foreign elements rise. From these studies M. Dumas passes on to the *irreversible transformation*, dealing with it at some length, and showing that variations in nickel content are to some extent equivalent to variations in temperature. This leads to a comparative study of steels of slightly different composition combined in such a manner that they have or have not undergone transformation at ordinary temperature. This is illustrated by two comparative tests, each steel containing about 15 per cent. nickel. In one, carbon is low and chromium absent, hence the steel has undergone tranformation. In the other, carbon and chromium are present, hence the steel is non-magnetic. The tests are as follows:—

					Elastic Limit.	Tensile Strength.	Elongation.	Contraction
	C.	Mn.	Cr.	Ni.	Kilogrammes	Kilogrammes	Per cent.	Per cent.
Magnetic Steel ...	0·16	0·13	—	15·92	76·2	89·2	19	54·5
Non-magnetic Steel	0·53	0·83	3·02	16 05	32·8	77·5	73	68·0

Turning to the reversible transformation, it is pointed out that, although without influence on the mechanical properties, it has none the less an important effect on physical properties. The most noteworthy is that which it exerts on the co-efficient of dilatation. This co-efficient diminishes considerably on the steel undergoing the reversible transformation on cooling, to such a point that, at ordinary temperatures when the steel contains 36 per cent. nickel it becomes nil. Guillaume has also described a variation in the modulus of elasticity resembling that in the co-efficient of expansion, which has some interesting applications, notably for the manufacture of self compensating springs in watch manufacture. This is an important consequence of the reversible transformation.

The Influence of Nickel and Carbon on Iron.—In conducting this research, Mr. G. B. Waterhouse has as an object the investigation of ternary alloys of iron, carbon and another metal, the third element in the present case being nickel. In preparing the alloys an effort has been made to keep the nickel constant and vary the carbon from 0·4 to 1·6 per cent. The contents of nickel and mechanical properties of the alloys are embodied in the table at bottom of the page.

The letters A and B refer to the treatment of the bars before testing. Thus A represents bars heated to 1,000° C. and cooled in air, the object being to recrystallise the steels and remove any distortion induced by rolling. B represents bars kept at a temperature of from 870° C. to 880° C. for three hours, and then slowly cooled. Corresponding to the increase in tenacity with the rise in carbon, there is a decrease in ductility which reaches a minimum of about 1·2 per cent. carbon. From thence ductility rises as the total carbon increases, this rise being accompanied by a separation of graphitic carbon.

The Nature of Troostite.—Troostite is a debatable term in the metallography of steel, and Dr. Carl Benedicks prefaces his paper by the statement "that its existence can certainly no longer be questioned," however tritely adding "that opinions as to its nature are divided." Thus it has been stated to be carbonless, whilst on the other hand troostite is described as containing varying amounts of carbon. Yet

No.	Ni.	CC.	Gr.	Elastic Limit. Tons per sq. in.	Maximum Stress. Tons per sq. inch.	Elongation. per cent. on 2".	Reduction of area per cent.
K A	3·79	0·41	—	21·68	40·28	26·0	44·75
K B	3·79	0·41	—	20·74	31·94	28·0	49·4
L A	3·79	0·51	—	22·52	44·24	21·0	39·05
L B	3·79	0·51	—	18·66	34·75	25·5	46·78
M A	3·76	0·63	—	25·01	51·52	16·5	26·27
M B	3·76	0·63	—	18·83	39·0	23·5	41·45
N A	3·81	0·79	—	29·84	60·55	14·0	21·27
N B	3·81	0·79	—	17·79	41·25	17·5	30·11
P A	3·79	0·92	—	35·04	69·42	8·0	14·8
P B	3·79	0·92	—	17·71	46·45	15·0	22·61
O A	3·75	0·97	—	35·76	70·01	7·5	8·39
O B	3·75	0·97	—	17·87	46·46	13·0	22·43
Q A	3·81	1·24	—	45·44	75·31	3·5	3 20
Q B	3·81	1·24	—	18·38	50·74	11·0	17·21
R A	3·82	1·21	0·31	29·25	65·01	10·5	13·9
R B	3·82	0·50	1·02	17·34	46·84	14·5	20·96
S A	3·92	0·93	0·71	30·18	60·59	11·5	17·86
S B	3·92	0·21	1·43	17·81	29·34	27·5	46·89
T A	3.79	0·91	0·91	29·66	58·76	12·0	13·92

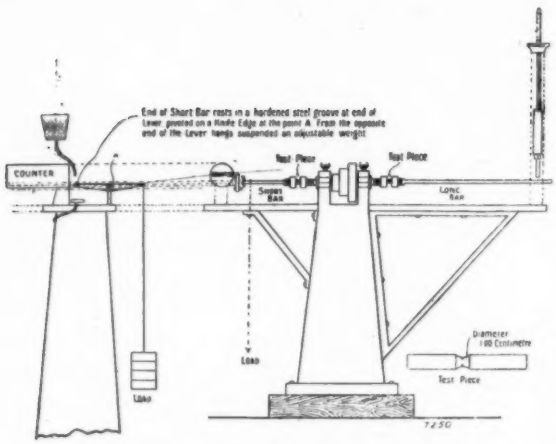

End of Short Bar rests on a hardened steel groove at end of Lever pivoted on a Knife Edge at the point A. From the opposite end of the Lever hangs suspended an adjustable weight
COUNTER
Test Piece
Test Piece
Short Bar
Long Bar
Load
Load
Diameter 1.00 Centimetre
Test Piece
7450

FIG. 2.—RICHARD'S AND STEAD'S MACHINE FOR TESTING STEEL BY REVERSAL OF STRESS AND STRAIN.

again it has been indicated to be β iron, and on the other hand γ iron. In face of this complexity of opinion the author has a difficult task in ascribing nature to a product erratically, and in the opinion of many erroneously described as "troostite." The task is, however, reasoned out, and the facts when marshalled are "in entire accord with the hypothesis that troostite is a pearlite with ultra-microscopically small particles of cementite."

Overheated Steel.—Messrs. A. Windsor Richards and J. E. Stead preface their paper by definitions of overheating and burning. Thus overheating is heating to any point below that which produces incipient disintegration, and results in the formation of large crystals. On the other hand, burning is heating at or above the point at which such disintegration occurs; burnt steel is nearly always coarsely crystalline. In connection with these definitions it should be remembered

(1) That all overheated steel is more or less coarsely crystalline.

(2) That different steels apparently of the same composition vary in their susceptibility to disintegration. At a given high temperature one may be simply overheated whilst another may be burnt and partially disintegrated.

(3) That burnt steel cannot be completely restored by reheating; it can be greatly improved, but is never equal to reheated steel which has not suffered partial disintegration.

In their experimental work the authors have applied a variety of tests including tension, bending and reversal of stress. In addition, alternate bending tests have been made by bending strips backwards and forwards through an angle of 40 degrees until fracture; the number of bendings being recorded in each case. Testing by reversal of stress was conducted in a machine designed by the authors which represents an improved form of one previously described by them. This machine is shown in the appended figure, and consists of a strong steel spindle, on which are mounted three pulley wheels, giving speeds of 800, 1,200 and 2,400 revolutions per minute. Each end of the spindle terminates in a modified form of self-centring chuck in which the test pieces are securely fastened. To one end of the machine is attached a short steel bar 10 ins. long, also with a suitable chuck which is connected to the spindle by the test piece, one end of the bar running free, and having a groove in which is loosely fitted one end of a lever carrying the load used in testing. The other end of the machine is similarly fitted, the bar being forty-two inches long, and the load applied by means of a spring balance following the plan of Ewing and Humfrey. A suitable counter for recording the number of revolutions is attached. The test pieces employed were four inches long by half-inch diameter, the centre of each being reduced as shown in the sketch.

Turning to the experimental results, tests were made on a series of three steels, each steel being in five distinct conditions, viz.:—

1. As received from the rolls and termed normal.

2. Overheated, *i.e.*, heated to about 1,300 C. and maintained there from two to three hours.

3. Reheated, *i.e.*, overheated steels raised to a temperature of 880° C. and air cooled.* This treatment applies to series G and H; series F were heated to 950° C.

4. Annealing, *i.e.*, slow heating to a temperature of from 850° to 880° C. followed by air cooling.

5. Sorbitic treatment, *i.e.*, heated to 900° C., quenched in cold water and reheated to 330° C. for twenty minutes and then air cooled. This treatment applies to series H. The three steels in the foregoing conditions give rise to a series of exceptionally interesting results, which, for convenience, we combine in one table (see next page).

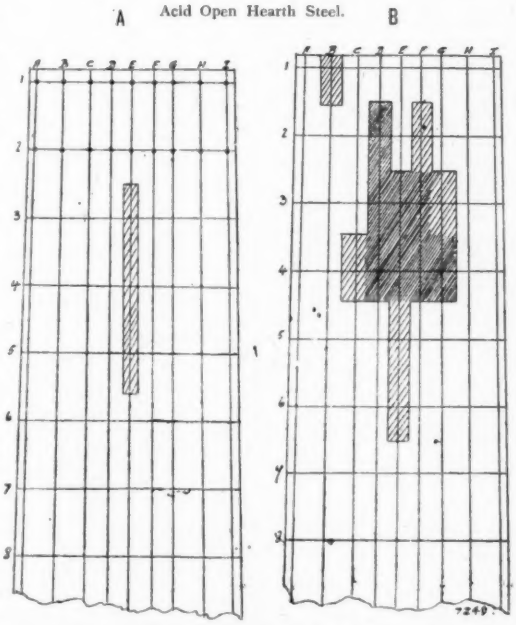
These results speak for themselves, it may however be noted that all systems of testing prove that overheating reduces the power of the steel to resist fatigue; that reheating such steel more than restores the original good qualities of the rolled bars; and that when the steel has its carbon in the sorbitic condition its power of endurance is more than doubled.

* The bars were packed in tubes, and air cooling refers to the tube and its contents.

Series.	C. per cent.	Condition.	Tensile Tests.				Alternate bending through an angle of 40 degrees.		Resistance to alternating Fibre Stresses.		
			Yield point. Tons.	Ultimate stress. Tons.	Elongation per cent. on 4″.	Contraction of area per cent.	Average bends to produce fracture.	Comparison normal = 1.	Total revolutions to produce fracture.	Comparison normal = 1.	Fibre stress. Tons.
F. 1	0·06	normal	16·05	24·4	35·0	66·3	48	1·0000	13,560	1·0000	25
F. 2	,,	overheated	14·75	23·8	33·0	60·8	36	0·7500	9,760	0·7197	25
F. 3	,,	reheated	15·85	24·2	40·0	67·1	53	1·1041	14,500	1·0693	25
F. 4	,,	annealed	15·65	23·6	37·0	70·9	52	1·0833	14,200	1·0471	25
G. 1	0·48	normal	27·2	45·8	19·0	34·5	115	1·0000	83,550	1·0000	28
G. 2	,,	overheated	27·4	46·9	10·0	26·5	51	0·4434	38,660	0·4627	28
G. 3	,,	reheated	27·0	45·8	22·0	38·6	116·3	1·0113	111,500	1·3226	28
G. 4	,,	annealed	22·0	48·3	21·0	36·5	115·3	1·0026	103,130	1·2344	28
H. 1	0·44	normal	21·7	40·2	23·0	48·8	117	1·0000	1,432,500	1·0000	25
H. 2	,,	overheated	20·6	41·3	12·0	20·6	72	0·6125	844,950	0·5891	25
H. 3	,,	reheated	22·0	40·2	25·0	51·1	132	1·1271	2,080,440	1·4528	25
H. 4	,,	annealed	21·3	39·9	24·0	50·0	139	1·1000	1,971,000	1·3773	25
H. 5	,,	sorbitic	43·4	55·1	25·0	56·8	263	2·2444	3,517,200	2·4570	25

Segregation in Steel Ingots.—Mr. B. Talbot records a large series of observations which show that the presence of aluminium has a decided tendency to prevent segregation. The results are drawn from parallel tests on ingots from the same heat with and without aluminium. In weight the ingots varied from one-and-a-half to three-and-a-half tons, and it is noted that the smaller ingots showed the effect of segregation quite as distinctly as the larger ones. As a rule ingots containing no aluminium show excessive segregation down a central line commencing from about six inches from the top and terminating about half-way down the ingot. In relative order of segregation, sulphur is first, phosphorus second, carbon third, and manganese last, segregation of the last element being almost negligible. Taking sulphur as an example, the appended diagram typifies the effect of aluminium in retarding segregation of this element. The author's practice in adding aluminium is to use from three to four ounces per ton of steel, adding it to the ingot when the mould is approximately two thirds full. The chief result to be obtained by the use of aluminium will lie in the decreased amount of crop ends due to the greater solidity of the top and the lessened amount of segregation in this top part of the ingot.

The Presence of Greenish Coloured Markings in the Fractured Surfaces of Test Pieces.—Captain H. G. Howarth



FIGS. 3 AND 4.—SHOWING SEGREGATION OF SULPHUR IN THE SAME HEAT IN THE CASE OF TWO INGOTS. A WITH ALUMINIUM, B WITHOUT ALUMINIUM. PARTS SHADED SHOW THE AREAS IN WHICH THE SULPHUR HAS INCREASED 25 PER CENT. OVER LADLE TEST. THE DARKER SHADING SHOWS APPROXIMATELY AREAS WITH OVER 75 PER CENT. INCREASE OF SULPHUR.

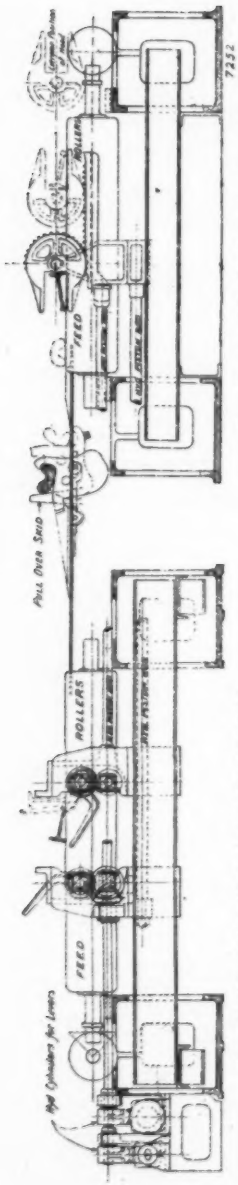


FIG. 5.—A MANIPULATOR FOR STEEL BARS.

records a series of interesting and important examinations of coloured defects noted in the fractures of gun steel test pieces. These defects are occasionally visible to the naked eye, but in the majority of cases require aided vision for their recognition. In colour they vary, that of a sulphur, yellow streak tinged with green being the most common, and next in order come minute leaf green markings. The latter are seldom massive, but occur as interrupted streaks in series, and in some cases as much as 10 per cent. of the fractured surface is occupied by them. Cream and bronze coloured defects have also been noted. The defects described are as a rule elongated in the same way as the slag lines in a bar of wrought iron, but irregularly shaped patches are not uncommon. Considering the high quality of gun steel the number of defects noted is surprising, and it is worthy of note that in the majority of cases the defects are found at the bottom of the ingot. Thus from fifty forgings 5 per cent. of the test pieces from the muzzle-end, and 35 per cent. of those from the breach-end were found to contain greenish defects. The muzzle-end of a forging in all cases represents the upper portion of an ingot. As in a normally cooled ingot one would expect the impurities to rise to the upper end which is removed before forging, or to the centre from which test pieces are not taken, their presence leads to the supposition that the steel first falling into the mould solidifies rapidly, and the particles of foreign matter become entangled. This would seem to be the explanation of the fact that the breach-end of the larger forgings contain the most defects. Concerning the nature of the defects, it is noted that they have (1) an optical similarity to the involved slag of wrought iron, (2) a resemblance by transmitted light to Siemens Martin slag, (3) and that the content of sulphur in gun steel is not sufficient to account for the large quantity of greenish matter found at the bottom of large ingots. These considerations lead to the recognition of two substances essentially distinct, but possessing similar optical properties, one of which is the dove grey sulphide of manganese described by Arnold. The second substance is unattacked by dilute sulphuric acid, and has been shown by Stead to be a sesquisilicate of manganese. Various types of these defects are shown in a series of photomicrographs, and the author emphasises the importance of their further investigation. From the point of view of gun steel this importance is specially shown by the fact that the locus of the defects reaches its maximum in the very worst place, *i.e.*, at the breach end of a large forging. In the inner tube it is at the front end of the chamber where erosion commences under normal conditions and these defects running longitudinally, whilst they may or may not develop into cracks, will in all probability form starting points for erosion.

Wear of Steel Rails on Bridges.—Mr. Andrews gives, at some length, the results of his

examination of a rail which fractured in main line surface on a bridge. Chemical analyses show that carbon, sulphur, and phosphorus had locally segregated to considerable extent around the outer periphery forming the contour of the rail head. The following analyses illustrate this variation and show the amount of segregation as observed in drillings taken from near one of the fractures.—

Position in Vertical Section.

	Top of rail head.	Junction of rail head with web.	Rail bottom.	Approximate maximum percentage of segregation.
Carbon ...	0·520	0·320	0·450	62½
Silicon ...	0·097	0·086	0·088	12½
Manganese	1·413	1·334	1·441	8
Sulphur ...	0·079	0·044	0·077	79½
Phosphorus	0·078	0·046	0·075	69½

Tensile tests show a similar range of variation, in particular elongation ranging from 3 per cent. in the bottom flange to 29 per cent. in the junction of head with web. Microscopical examination supports the chemical and physical and on the whole the author considers one of the chief causes of fracture to lie in the defective and segregated chemical composition of the rail. Both carbon and manganese in the top of the rail head and in the bottom flange were in excess of what should obtain in good rail steel. The composition was undesirable and such as is liable to lead to brittleness and sudden fracture in rail service.

A Manipulator for Steel Bars.—The illustration opposite gives the principles of the three machines comprising the manipulator described by Mr. Upton. The first machine, A, consists of two pairs of movable heads, installed at each side of the roughing and finishing rolls, These heads move in either direction parallel to the rolls, and place the piece in position for entering at any required pass. Moreover, the heads are fitted with levers for turning the piece up for edging purposes, and will maintain it in that position until it enters the rolls. The second machine B is designed to turn the piece over between the roughing and finishing rolls. With large sections such as bulb tees it is necessary to turn the bar completely over at each side of the finishing rolls, and for this purpose the third machine C is employed. The manipulator has given excellent results in the large mill in which it has been employed.

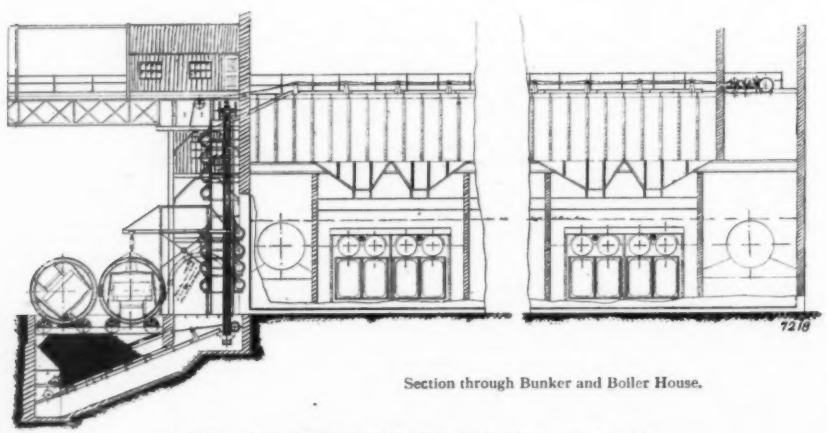
The use of Vanadium in Metallurgy.—Steel used for Motor Car Construction in France.—M. Guillet is responsible for these two papers, the first of which, though occupying fifty pages of the proceedings is largely of a summary character and the researches dealt with have already been noted in these columns. Turning to the second paper, it is shown that the steels actually in use comprise nickel, chromium, silicon, nickel-chromium, and a type the composition of which has not yet been published. Nickel steels of low carbon are used for parts which are subsequently case hardened, such as shafts and gears which engage directly. Steels of medium carbon and low nickel are used after quenching and reheating for a large number of parts, shafts, pinions, gearing, &c. Steels low in carbon and high in nickel are used for valves. Chromium steels of high carbon and low chromium are used for bearings. Whilst silicon steels are used for springs and gearing. Nickel-chromium steels, low in both special elements, are used for parts requiring resistance to shock and a certain degree of hardness.

Coal-Handling Plant at the Metropolitan Electric Supply Co., Ltd.

THE METROPOLITAN ELECTRIC SUPPLY CO., LTD., whose works are situated at Acton Lane, Willesden Junction, N.W., is, as is perhaps generally known, responsible for the lighting of large metropolitan areas lying between Notting Hill Gate and Hatton Garden on the one hand and Kilburn and Charing Cross on the other.

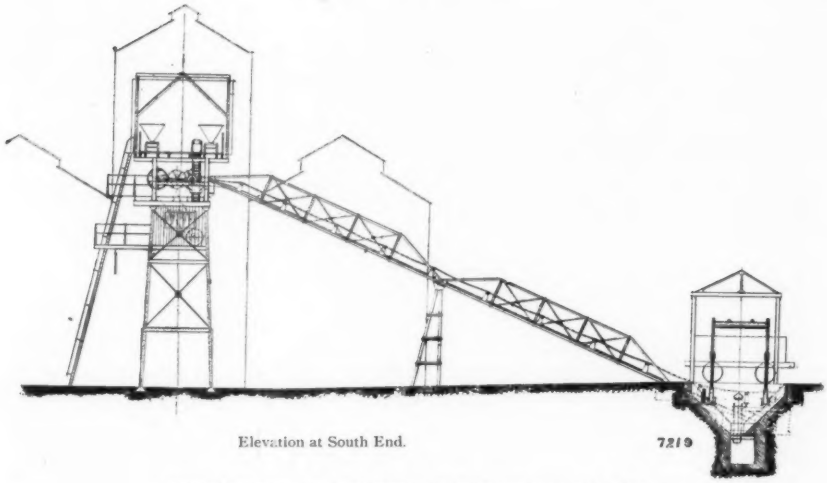
The plant is, in every respect, up to date, and has in the main been fully described in the columns of our contemporaries. A recent addition, however, calls for description, and to which we shall confine our attention—namely, the coal-handling plant installed by Messrs. Ed. Bennis & Co., Ltd., for handling small coal at the rate of from sixty to eighty tons per hour and conveying it from the trucks to the furnaces. The loaded wagon or coal truck is turned over bodily, and its contents fall into the hopper built to receive them, and pass thence into the conveyor. One of the most novel features of this system of conveying is that it entirely does away with any form of bucket elevator, the whole of the fuel being elevated and conveyed with the "Bennis" type of U-link chain conveyor.

Opposite the boiler house are two main lines of railway. A large coal receiving bunker, of seventy tons capacity, has been built below the coaling lines. Immediately over the top of this bunker are mounted two of the "Bennis" Patent Rotary Side-Truck Tippers, which enable the trucks to be run on the table of the "Bennis" Revolving Tipplers. Each tippler has a diameter of 18 ft., which is sufficient to permit the engine to pass right through. The wagon is secured in the tippler by booms, which when tightened up hold it perfectly in place. The boom is provided with a strong compensating mechanism to take up any shock. This special feature of the tippler ensures that the truck is held down securely so that it cannot move. A 5 h.-p. motor rotates the tippler containing the truck, from which latter the fuel is delivered into the receiving hopper to be taken away by the conveyor. One specially



Section through Bunker and Boiler House.

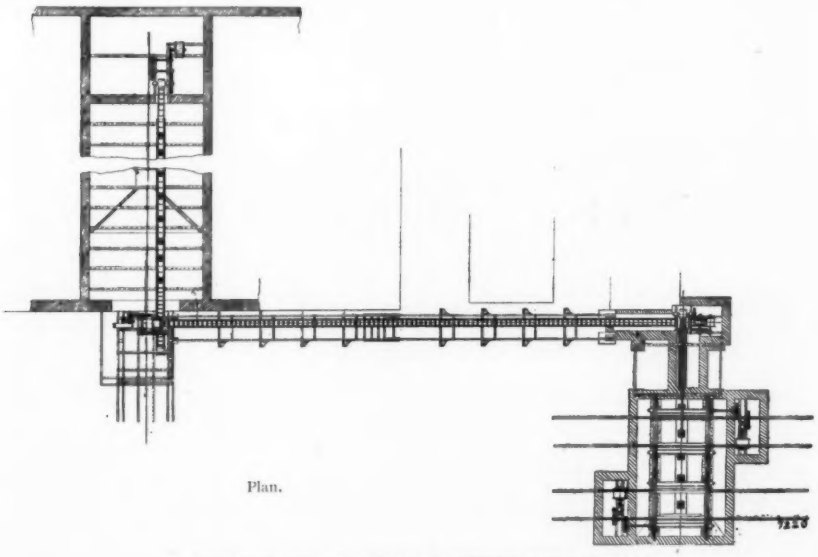
COAL-HANDLING PLANT, METROPOLITAN ELECTRIC SUPPLY CO., LTD.



Elevation at South End. 7219

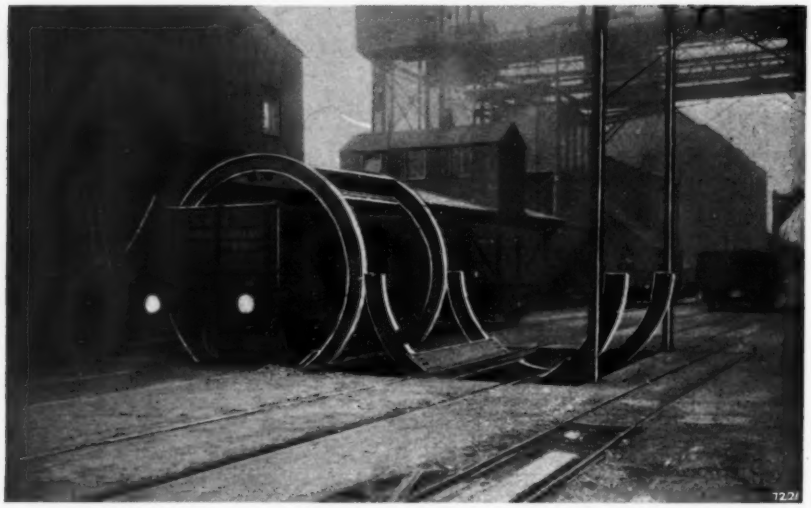
COAL-HANDLING PLANT, METROPOLITAN ELECTRIC SUPPLY CO., LTD.

interesting point to be noticed in the design of the tippler is that by its complete revolution it saves trimming, while clearing every ounce of coal. Each tippler is capable of emptying 100 tons of coal per hour. It may be noted that the tippler rings are so proportioned that their centres coincide with the centre of gravity of the truck in end elevation. The advantage of this is obvious, little power being required in working the tippler, merely sufficient, in fact, to overcome the friction in turning.

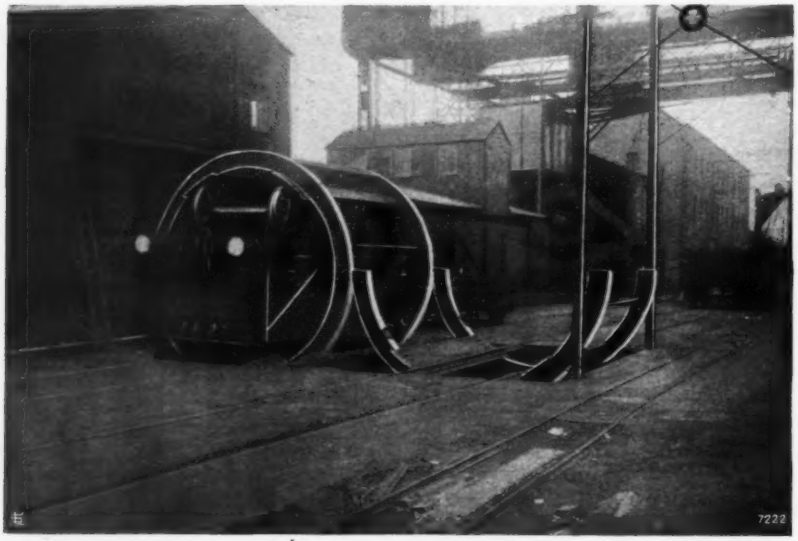


Plan.

COAL-HANDLING PLANT, METROPOLITAN ELECTRIC SUPPLY CO., LTD.



REVOLVING TIPPLER AT THE METROPOLITAN ELECTRIC SUPPLY CO., LTD.



REVOLVING TIPPLER: A TRUCK REVERSED

The system of conveying may be described as consisting of a series of chains in specially constructed troughs. The coal is conveyed through shoots with adjustable cut-off slides. The cross chain is placed immediately beneath the coal receiving bunker.

The cross conveyor partly elevates the fuel and delivers it on to the main inclined elevator conveyor, which runs at an angle of 30 degrees, elevating its load through a height of 40 ft., and delivers it on to the main distributing conveyor, running the full length of the overhead storage bunkers. The bottom of the distributing conveyor, as we have already implied, is fitted with openings and cut-off slides at intervals of 3 ft., which enables the fuel to be delivered at any point in the length of the bunker.

Each section of the conveyor is driven by means of a separate motor through substantial spur-wheel reduction gear.

The elevator conveyor is sheltered from the weather by galvanised iron sheeting. The power required for the working of the entire system of conveyors is stated to be as low as 25 h.-p., the capacity of the conveyor being from 60 to 80 tons per hour from the receiving hopper to the coal bunkers.

The trough in which the U-shaped chains run is $\frac{5}{8}$ in. thick, 15 in. wide, and 8 in. deep. The chain itself consists of a series of U-shaped links made out of $2\frac{1}{4}$ in. by $\frac{1}{2}$ in. flats formed into links of 12 in. pitch, and secured at the joints by special $\frac{7}{8}$ in. rivets and washers. The links are made of Siemen's Martin acid steel, of a tensile strength from 28 to 32 tons to the square inch, with an elongation of 20 per cent. in 8 in. The length of cross conveyor under tippler is 38 ft.; of incline conveyor 106 ft.; of bunker conveyor 395 ft., giving a combined length of 539 ft.

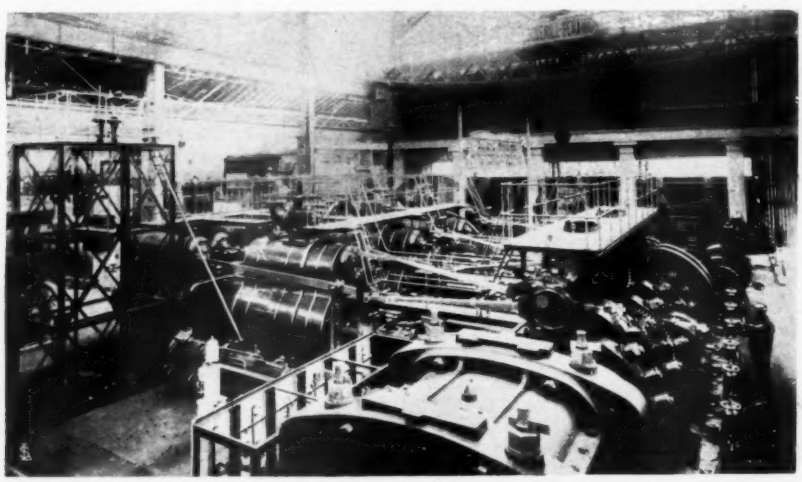
The saving effected over the old system by the installation of this coal handling plant, from trucks to bunkers, is stated to be as high as 80 per cent.

In conclusion it may be mentioned that mechanical stokers of the well-known "Bennis" type have been fitted to the "Lancashire" type boilers at this power house.

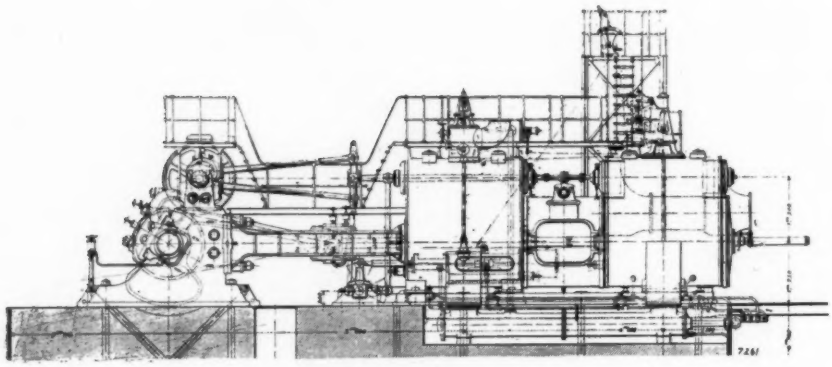
Ten-thousand Horse-power (indicated) Reversible Rolling-mill Engine.

THE engine shown by John Cockerill, Limited, of Seraing (Belgium), is probably the most powerful machine of its kind in the world.

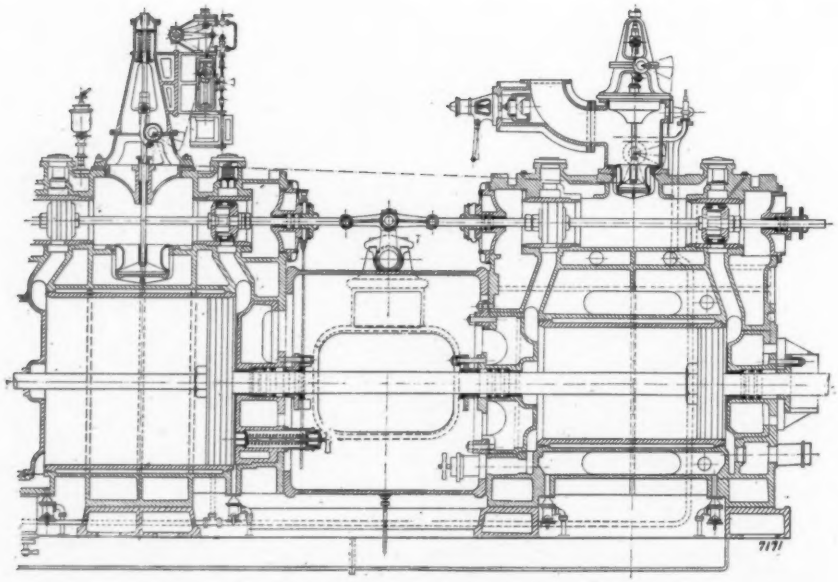
It is to be employed for driving the blooming-mills of the Cockerill steel works at Seraing, where hitherto units not exceeding 1,800 h.-p. have been at work. This fact may cause surprise; but even at Krupp's Essen works no such powerful modern engines are used for the rolling mills, or at least were not up to the year



10,000 H.-P. ROLLING-MILL ENGINE FOR THE COCKERILL WORKS AT SERAING (SHOWN AT LIÈGE EXHIBITION).



10,000 H.-P. ROLLING-MILL ENGINE.



10,000 H.-P. ROLLING-MILL ENGINE: DETAILS OF CYLINDERS.

1904, whereas at the Hungarian State Railroad's steel works at Diosgyör an engine of 4,200 effective h.-p. has been in use for some years, and at the Creusot steel works (Schneider & Co.), France, there is a machine of 8,000 i.h.-p., while some other French steel works—less universally known than Krupp's, Cockerill's, or Terni (Italy)—have also very large three-cylinder engines, but always much less in size than the Cockerill engine.

This new engine is a triple tandem compound with three cranks set at 120 deg.

Each high-pressure cylinder, at the front end of the engine, has one piston valve, and each low pressure cylinder, in the rear, has two piston valves. All the piston valves throughout are identical and interchangeable. The three valve spindles of each group of two tandem cylinders are operated from rocking shafts worked direct from the Allan-type reversing-links. The bearings for the rocking-shafts are bolted on each side of that casting which forms the connection between the pairs of tandem-cylinders.

The reversing gear-shaft is worked by an auxiliary steam cylinder with oil cataract which is clearly shown in the foreground of our view and by the dotted lines in the elevation, it being located on the right-hand side of the engine immediately below the engineer's platform, which is built up clear to one side of the machine from whence the engineer can observe all the valve motion, which is also placed on the right-hand side of each pair of tandem cylinders, while, on account of its great height, it gives a clear view of the rolling-mill cylinders and connections.

The control of all the main steam valves, for admission on the high-pressure cylinders and for exhaust to the steam-jackets in the low-pressure cylinders, is also effected by a steam servo-motor which is bolted to the vertical casing of the middle cylinder low-pressure drop-valve. The levers for operating the assistant motors are placed on the high platform, and the closing of the three last mentioned drop-valves (435 mm. diam.) is rendered simultaneous with the shutting of the main steam admission throttle on the high-pressure cylinders by means of the connecting rods between the two valves visible in the drawings. This arrangement was patented in 1882, by the Société Cockerill, its purpose being to maintain the pressure in the reservoirs whilst the machine is idle, and when the condensation in the low-pressure steam-jackets would be excessive.

It will be understood from the foregoing that the steam, when admitted by the main throttles, circulates around the high-pressure cylinders as also the high-pressure valve-chests, and after working it is exhausted into the large receivers located below, and to the right-hand side of each pair of tandem cylinders thence to enter direct the low-pressure valve-chests, the exhaust from the low-pressure cylinders, after work therein, passing through the jackets to the two large exhaust conduits located on each side of the middle cylinder. Relief safety valves are provided in all the cylinder covers, the discharge passing to the exhaust of each group of cylinders.

The valve motion shaft carrying the eccentrics is driven from the main crank shaft by means of two pairs of spur pinions.

The cheeks and counterweights of the cranks are one piece steel-castings built together with forged steel pins of the same diameter as the shaft itself, that is 430 mm. The cross-head guides are steel castings of I-section, two to each main rod, and they form the only connection between the cylinders and the crank shaft pedestals, there being no bed plate to the engine.

The three high-pressure cylinders are $35\frac{1}{2}$ in. diameter and the three low-pressure $53\frac{1}{4}$ in. diameter, the piston stroke being 51 in. The effective steam pressure is $117\frac{1}{2}$ lbs. and the effective horse power is 8,000 h.-p., or at 120 revolutions, 10,000 i.h.-p.

The cylinders are sheathed in polished Russian iron, and are accessible throughout by three bridges crossing the engine and by gangways from the cylinders to the motion work and thence to the bridge platform over the cranks.

At one side of the engine, but disconnected from the shaft, are shown at the Exhibition, the mitre-teeth cog-wheel connections with the rolling-mill—which latter consists of four pairs of rolls for blooming and for heavy girder sections.

There are, it will be observed, no separate reservoirs for the steam arising from the boiler. The steam reservoirs are constituted by the steam jackets of the high-pressure cylinders. This method of forming reservoirs for high-pressure steam or receivers for low-pressure steam is a very notable feature in the Cockerill engines exhibited at Liége.

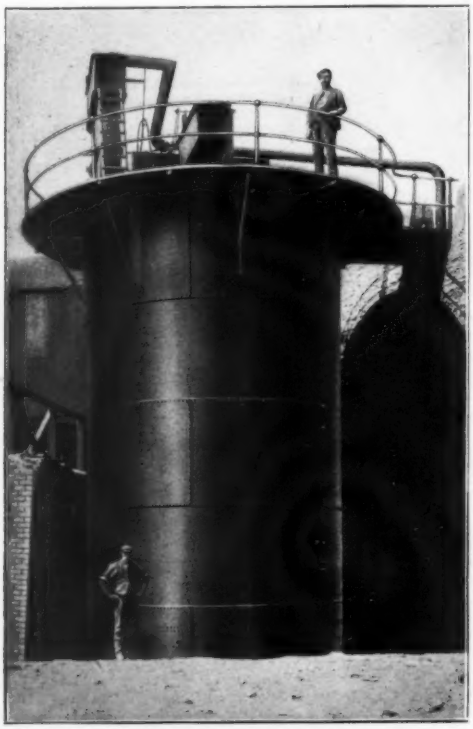
Opening of the Bournemouth-Christchurch Tramways.

THE formal opening of the extension of the Bournemouth electric tramway system to Christchurch last month constitutes a

unique event in the history of tramway municipal enterprise, the completion of the new length giving to the Bournemouth Corporation control of lines within three separate municipalities. The whole system now comprises a route ten miles in length, extending from Poole on the west to Christchurch on the east, the new length extending 3½ miles from Boscombe to the western terminus. The inaugural ceremony was attended, at the invitation of the contractors, Messrs. J. G. White & Co., by a number of engineers and representatives of the technical press, a special train being placed at their service, making a non-stop run from Waterloo in two hours ten minutes. On arrival the company left in decorated cars for the Square, from which place the run was made to Boscombe, where the new line was entered upon. Christchurch being reached, the members of the party, the mayors, town clerks, and chairmen of the several tramway committees, alighted, and were welcomed to the ancient borough by the mayor. The return journey was made direct to the Square at Bournemouth, from whence the party proceeded to the Winter Gardens, where the Mayor and Mayoress of Bournemouth held a reception.

The new length is equipped throughout on the overhead system, and is practically all double track. In Bournemouth itself, however, it will be remembered that the system employed is a combined conduit and overhead, and which during the period of its working has given complete satisfaction. The side slot is used, being incorporated with one of the running-rails, a method which exposes less metal on the surface of the road, besides being cheaper in construction than the centre slot. Bournemouth, it may be mentioned, enjoys the distinction of having been the first to adopt the conduit system, a step which has been amply justified, the co-operation of Messrs. J. G. White & Co. and of their chief engineer, Mr. A. N. Connett—the first authority on conduit systems—having been secured in the construction. The change from the conduit to the overhead is performed with facility, only 20 seconds sufficing to effect the alteration.

One of the features of the new length to Christchurch is the new bridge carrying the track over the river Stour. This is constructed throughout of ferro-concrete, and is one of the first of its kind erected in this country. In the evening a banquet, presided over by Mr. J. G. White, was given at the Grand Hotel, some 150 guests being present. Excellent speeches were made by, amongst others, Mr. J. H. Rider, electrical engineer to the London County Council Tramways; Mr. A. N. Connett, Mr. F. W. Lacy (borough engineer), Mr. T. O. Callender and the Mayor of Bournemouth, the latter eulogising the conscientious manner in which the contractors, Messrs. J. G. White & Co., had carried out their work.



"KENNICOTT" WATER SOFTENING PLANT FOR PONTYPOOL.

An Up-to-Date Water Softening Plant.

THE accompanying illustration shows a "Kennicott" water softener capable of dealing with 6,000 gallons of water per hour, recently supplied to the Tirpentwys Black Vein Colliery, Pontypool, South Wales. The water to be treated is very dirty, and contains oil

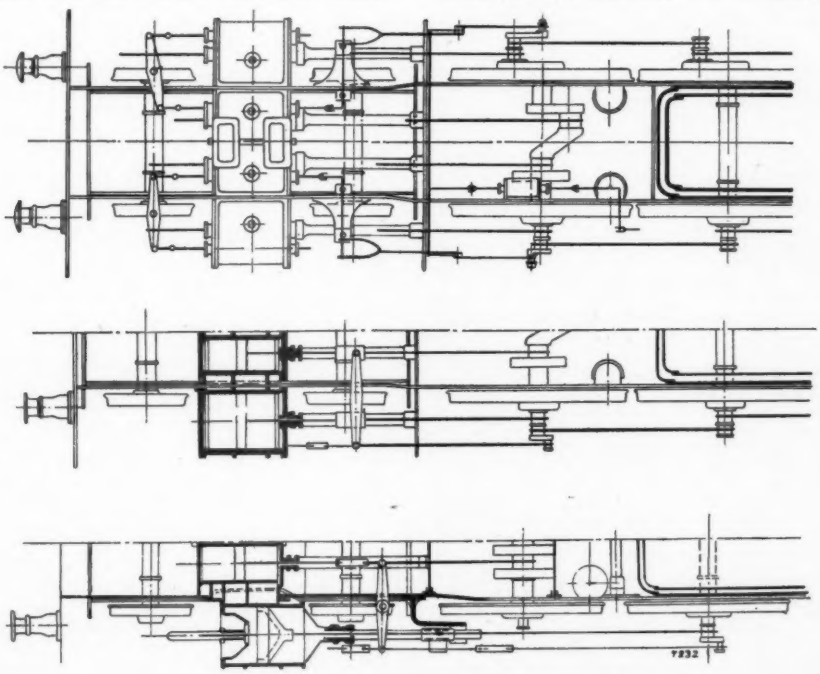
from the cylinders of condensing engines. The hardness of the raw water varies from about 27° Clarke to 33° Clarke, and it has been continuously reduced to about 4° Clarke, emerging from the softener clear, sparkling, and free from oil.

A brief description of this up-to-date plant may be of interest.

On the left of the illustration at the top, is seen the water-wheel over which the hard water is pumped on its way to the softener. The receptacles for dissolving the reagents, and the apparatus for automatically varying the quantities of reagents in proportion to the amount of water passing through the softener are also placed, and extending nearly to the bottom of the machine is the lime saturator, in which the lime is thoroughly agitated with soft water by a stirrer driven from the water-wheel. In a compartment at the top of the lime saturator is the mixing chamber, where the hard water, after being heated by exhaust steam, is thoroughly mixed with the lime water and soda solution by rotating vanes moving past fixed vanes. The mixture then overflows into the conical downtake, where the precipitation is completed, and partial settlement takes place. Owing to the conical shape of this part of the machine, the rate of flow of the water is constantly decreasing, an arrangement which greatly assists the separation of the precipitate from the water. Arrived at the bottom of the downtake, the direction of the flow turns upwards through perforated baffle plates, to which the small amount of precipitate still left in the water clings. These plates are inclined at such an angle, that when a certain amount of sludge has accumulated upon them, it drops off by its own weight. Finally, the water passes upwards through a wood wool filter, and it is then ready for use.

Locomotives at the Liege Exhibition.

THE accompanying illustrations show the details of the motion of the engine systems based upon Central European practice (Figs. 1 and 2), as combined with the Webb principle according to the "Henry"



FIGS. 1, 2, AND 3.—LOCOMOTIVES AT THE LIEGE EXHIBITION.

(P.L.M.) compounds of 1888 (Fig. 3). These systems were referred to by Mr. C. R. King in his article on Locomotives of the Liége Exhibition.* It should be noted that the "Henry" arrangement consists of advancing the inner pair of cylinders, so as to gain more room for the inside connecting rods. Fig. 1 shows the "La Meuse" type, with normal Walschaerts' valve gear, but driving every valve through rocking-levers, in order to give central admission. Fig. 2 shows the arrangement adopted in Class 19. The Walschaerts' gear is reversed in its articulations, so as to give central admission to the outside valves, while the rocking-levers effect the re-reversal of direction for the inside valves, again effecting central admission. Fig. 3 shows the arrangement in Class 19A—the improved P.L.M. engine system, the valve motion being arranged as in Fig. 2.

BOOK REVIEWS.

The World's Locomotives. By CHARLES S. LAKE. (London: Percival, Marshall & Co.) Price, 10s. 6*d.* net.

The subject which the author deals with in this volume is of peculiar fascination to the great number of people interested in modern locomotives. Mr. Lake has succeeded in gathering together in the form of a readable volume particulars of the various existing types of locomotives in Great Britain, the Continent, and America, with the object of bringing into comparison the efforts which are being made, the world over, to cope with the ever-increasing demands for more powerful engines for working railway traffic. The volume contains descriptions of practically all varieties of locomotives, and the letterpress is profusely illustrated by a large number of photographs, plates, and diagrams. The mechanical engineer and draughtsman will probably regret that the theoretical part of the subject has not been more fully dealt with by the author. As a book of reference, the volume should, however, prove useful, and deserves a place in the library of every locomotive enthusiast. The opening chapter treats with a brief survey of the exigencies of locomotive design, reference being made to boiler design and construction as applied to locomotives in this country. Chapter II. is devoted to describing the different kinds of locomotive types, and the cylinder and wheel arrangement. With the exception of Chapter IX., the rest of the book is mainly descriptive, and deals with every class of locomotive. We note that no description is given of the Belgian Mixed Traffic Locomotive, illustrated on page 246, and that no mention is made of the latest types of 4-6-0 and 4-4-2 compound express engines which have been built for passenger train service in Belgium. We should also have liked to have seen reference made to the decapod which was built for the Great Eastern Railway, and the locomotives of the Natal Government Railways, and some other colonial railways, but have no doubt that these omissions will be rectified in future editions, and the volume brought thoroughly up-to-date. In Chapter IX. the author deals with the various systems of compounding which have been applied to locomotives in this country. Mr. Lake is undoubtedly an advocate of compounding, and has himself designed an express locomotive on the Riekie system. The question of compound locomotives is one that has never met with much favour in this country, although it has been adopted with such success in France and on the Continent and in America. We maintain with leading locomotive engineers in England that the same power at high speed can be got out of a simple locomotive using an 18-inch cylinder as out of a compound using larger cylinders, and that the success of French and other express compound engines was largely due to increased boiler power and the arrangement of the cylinders, apart from the compound principle. The question continues, however, to remain a very debateable one. Interesting discussions on the subject were held at the Institution of Mechanical Engineers in June, 1900, and March, 1904, and no doubt the matter will be officially taken up at an early date. In conclusion, a word of praise is due to the publishers for the manner in which they have performed their part. The type, illustrations, and general appearance of the book are all excellent. There is also a very complete index, which should be a *sine quâ non* in such a work as this, but it is so frequently omitted that it is only fair to call attention to it when present.

Imperial Preferential Policy. By CHARLES BRIGHT, F.R.S.E. 1905. (London: P. S. King & Son.) 1s.

On behalf of the Tariff Reform League Mr. Charles Bright delivered, during the past two years, a series of three lectures at the Town Hall, Uxbridge, and these lectures are now published together in the present volume. They give a good presentation of the issues now before the country, and discuss the question of imperial preferential trade in all its aspects. They are very readable and are not overburdened with statistics, though useful extracts from official returns are used occasionally to give point to the argument. The first lecture is general in character, the second deals with some special points such as "dumping," and the third treats of the colonial aspect of the question.

* *Cf.* page 312.

In this section is presented every month a list of the principal contents of the leading organs of the technical press and of the proceedings of learned societies throughout Great Britain, the Continent, and America. An alphabetically-arranged list of the publications regularly reviewed, together with the place of publication and price, was given on pages 165—196 of the August issue.

CIVIL ENGINEERING.

Bridges.

Standard Bridges on the Harriman Lines. *Railway Gazette*, 16*th*, 22*nd*, 29*th September*, and 6*th October*, 1905.

The Anacostia Bridge, II. *Engineering Record*, 2*nd September*, 1905.

The 1,800 ft. Span Cantilever Bridge across the St. Lawrence River at Quebec. *Engineering News*, 14*th September*, 1905.

The Anatomy of Bridge Work—Strengthening of Riveted Bridges by Centre Girders. *Engineering*, 22*nd September*, 1905.

The Zambesi River Bridge. *Engineering Record*, 23*rd September*, 1905.

Reinforced Concrete Ribbed Arch Bridge at Deer Park Gorge. *Engineering News*, 21*st September*, 1905.

Erection of the Thebes Bridge Superstructure. *Engineering Record*, 16*th September*, 1905.

A Reinforced Concrete Double-Track Railroad Arch Bridge. *Engineering Record*, 9*th September*, 1905.

A Long Single-Track Plate-Girder Span. *Engineering Record*, 16*th September*, 1905.

Specifications for Structural Steel for Bridges, *Railway and Engineering Review*, 9*th September*, 1905.

Protection of Bridge Floors against corrosion. *Railway Engineer*, *October*, 1905.

Canals, Rivers and Harbours.

Notes on the improvement of River and Harbour Outlets in the United States. *Proceedings American Society Civil Engineers*, *September*, 1905.

Irrigation.

The Scioto River Storage Dam at Columbus, Ohio. *Engineering Record*, 9*th September*, 1905.

Method and Cost of Concreting Jerome Park Reservoir, New York City. *Engineering News*, 21*st September*, 1905.

Structural Steel Dams. *Engineering News*, 28*th September*, 1905.

Movable Dam and Lock of the Rice Irrigation and Improvement Association, Mermentau River, La. *Engineering News*, 28*th September*, 1905.

Miscellaneous.

Concrete Plant for the Brooklyn Anchorage of the Manhattan Bridge. *Engineering Record*, 9*th September*, 1905.

The Gibb's Hill Lighthouse, Bermuda. *Engineering News*, 31*st August*, 1905.

Coast Defence against Erosion. *Le Genie Civil*, 30*th September*, 1905.

New Design for Armoured Concrete Tunnels. *Engineer*, 15*th September*, 1905.

The Pennsylvania R. R. Tunnel under Capitol Hill, Washington, D.C. *Engineering News*, 14*th September*, 1905.

The New Roof Shield for the Metropolitan Railway Tunnel of Paris. *Engineering News*, 28*th September*, 1905.

BUILDING.

Construction and Design.

Steelwork of the New General Electric Machine Shop, II. *Engineering Record*, 2*nd September*, 1905

Steelwork of the Wanamaker Building, Philadelphia, I, II. *Engineering Record*, 2*nd* and 16*th September*, 1905.

A Unit Frame Reinforcement System of Concrete-steel construction. *Engineering News*, 31*st August*, 1905.

A new method of constructing Concrete and Pile Footings. *Engineering Record*, 30*th September*, 1905.

New Lackawanna Coal Piers. *Railway Age*, 15*th September*, 1905.

A System of Safeguards against Freezing in Concrete Building Construction. *Engineering News*, 7*th September*, 1905.

Heating and Ventilation.

Central-Station Heating Plants. *Western Electrician*, 16*th September*, 1905.

MEASUREMENTS AND MATERIALS.

Measuring and Mixing Powdered Materials. *Engineering, 22nd September*, 1905.

Proper Methods in Conducting Painting Tests, *Electrical Review, New York, 9th September*, 1905.

Reinforced Concrete as a Fire Resistant. *Engineering, 6th October*, 1905.

Cement and Concrete Tests at the St. Louis Exposition. *Engineering News, 21st September*, 1905.

Specific Gravity and Weight of Building Stone, Cements, and other Non-Metallic Structural Materials. *Engineering News, 7th September*, 1905.

The Manufacture of Sand-Lime Brick. *Engineering News, 31st August*, 1905.

MECHANICAL ENGINEERING.

Boilers, Furnaces and Fuel.

Superheated Steam. *The Mechanical World, 6th October*, 1905.

Engines and Motors.

300-B.H-P. Rowden Producer-Gas Engine. *Engineering, 15th September*, 1905.

Rateau Steam Regenerator System. *Electrical World and Engineer, 9th September*, 1905.

The Atlas Four-valve Engine. *Power, September*, 1905.

The Sargent Complete Expansion Gas Engine. *Power, September*, 1905.

An Investigation to determine the effects of Steam-jacketing upon the efficiency of a Horizontal Compound Steam Engine. *Marine Engineer, October*, 1905.

Timing the Ignition in Internal Combustion Engines. *Practical Engineer, 22nd September*, 1905.

Adjustment of Gas Engines. *Mechanical World, 15th September*, 1905.

Pointers on Indicator Diagrams. *Engineer, Chicago, 1st September*, 1905.

Power and Transmission.

The Distribution of Power. *Engineering, 22nd September*, 1905.

Individual *v.* Belt Drive in Electrically-operated Shops. *Mechanical World, 29th September*, 1905.

Hydraulics.

The Most Economic Type of Hydraulic Power Conduits. *Engineering Record, 2nd September*, 1905.

New Lardner's Point Pumping Station, Philadelphia. *Engineering Record, 16th September*, 1905.

Pumping Engines of the Budapest Waterworks. *Engineer, 22nd September*, 1905.

Results of Tests of a Forced Vortex Centrifugal Pump. *Practical Engineer, 29th September*, 1905.

The Hydraulic Plant of Bournillon, France. *Electrical Review, New York, 16th September*, 1905.

Compressed Air.

A New Gas or Air Compressor. *Engineer, 22nd September*, 1905.

Shop Equipment and Practice.

Cutting Speeds for Shapers and Slotting Machines. *Modern Machinery, September*, 1905.

High-Speed Radial Drilling and Lapping Machine. *Engineering, 29th September*, 1905.

Getting the most out of a Lathe. *American Engineer and Railroad Journal, September*, 1905.

6 ft. Universal Radial Drilling Machine. *Engineering, 15th September*, 1905.

Cone Pulley Radii. *Machinery, September*, 1905.

Improved Crankshaft Lathe. *American Machinist, 7th October*, 1905.

A Method of Making a Templet for Worm Gear Tooth Patterns. *American Machinist, 7th October*, 1905.

Up-to-Date Method of Moulding. *American Machinist, 23rd September*, 1905.

Large Thread Milling Machine. *American Machinist, 30th September*, 1905.

Miscellaneous.

A Combined Sewer Cleaner and Bucket. *Engineering News, 28th September*, 1905.

Strength of Laminated Springs. *Engineer, 15th September*, 1905.

The Transmission of Heat from Air to Water Through Corrugated Copper Tubes. *American Machinist, 16th September*, 1905.

RAILWAY ENGINEERING.

Motive Power and Equipment.

New 4-4-0 Type Locomotives, Caledonian Railway. *Railway Engineer, October*, 1905.

Vestibule Trains; Great Indian Peninsula Railway. *Railway Engineer, October*, 1905.

Express Locomotives. *Engineer, 15th September*, 1905.

Natal Government Railways—Eight-Coupled Locomotive. *Engineer, 15th September*, 1905.

Royal Train for India. *Engineering, 15th* and *29th September*, 1905.

Heavy Switching Locomotive, New York Central Lines. *American Engineer and Railroad Journal, September*, 1905.

Oil-Burning Locomotives. *Railway and Locomotive Engineer, September*, 1905.

75-Ton Steel Flat Car, Pittsburgh and Lake Erie Railroad. *American Engineer and Railroad Journal, September*, 1905.

Wheaton Variable Exhaust. *Railway and Locomotive Engineering, September*, 1905.

Hydrostatic Tests of Locomotive Boilers. *Railway and Engineering Review, 9th September*, 1905.

Superheating Ten-Wheel Engine—C., St. P., M. & O. Railway. *Railway Master Mechanic, September*, 1905.

New Type of Bavarian Four-Cylinder Compound Locomotives. *Railway Age, 15th September*, 1905.

Locomotive Firebars. *Mechanical World, 29th September*, 1905.

Steam Motor Coaches for the Buenos Ayres Great Southern. *Railway Gazette, 29th September*, 1905.

Slide Valve *v.* Piston Valve. *Railway Gazette, 6th October*, 1905.

Forging and Repairing Locomotive Motion Rods. *American Engineer and Railroad Journal, October*, 1905.

Compound Articulated Locomotive for the Northern Railway of France. *Engineering, 6th October*, 1905.

Steam Rail Motor Cars on the L. & N. W. R. *Railway Gazette, 22nd September*, 1905.

New Locomotives for the Indian State Railroads. *Railway Gazette, 29th September*, 1905.

Method of Installing Flexible Staybolts. *American Engineer and Railroad Journal, September*, 1905.

The Distribution of Weight in Locomotives, Four and Six-Wheeled Engines. *Practical Engineer, 6th October*, 1905.

Locomotive Tests with 250lbs. Pressure. *American Engineer and Railroad Journal, October*, 1905.

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